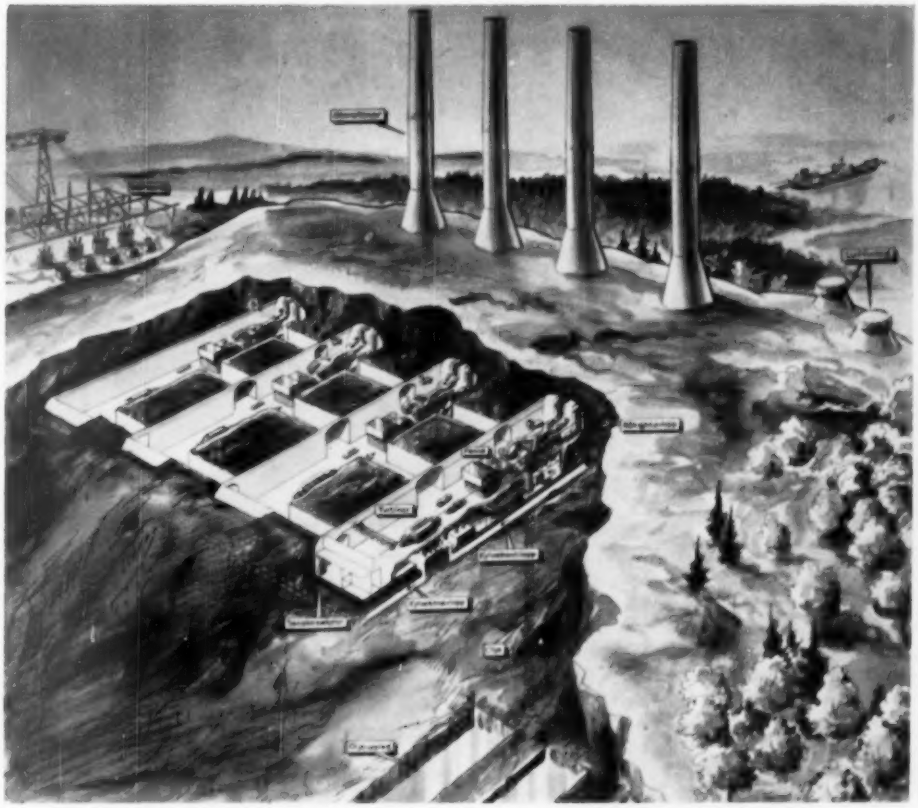
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



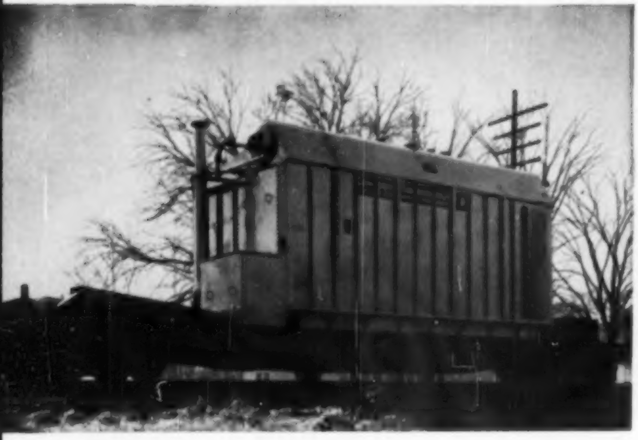
October 1960

Unique Underground Steam Station

Code Testing of Large Boilers

Non Destructive Techniques In Inspection

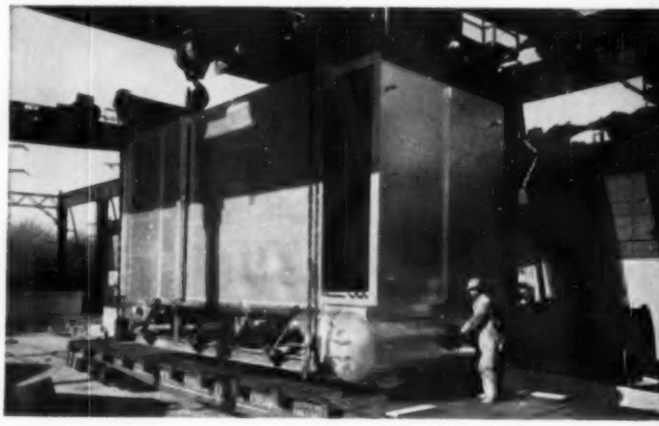
Radiant Heat Exchange In a Boiler Furnace



To 90,000 lb/hr . . . Type VP—A compact, economical, natural circulation, *package* boiler for the majority of industrial requirements. Steam capacities from 4,000 to 90,000 lb/hr; pressures to 700 psi; temperatures to 750 F. Most sizes shipped complete with firing equipment for oil or gas, setting and forced draft fan arrangement.

To 120,000 lb/hr . . . Type PCC—Shop-assembled *controlled circulation* boiler providing high output and high temperatures in a compact, high-performance unit. Capacities—80,000 to 120,000 lb/hr; pressures to 1,000 psi; temperatures to 900 F. Designed for minimum installation, operation and maintenance costs.

To 50,000,000 Btu/hr . . . Type HCC—High-temperature water boiler, shop-assembled, widely used for large-scale, economical heating of commercial and industrial installations—including many military air bases. Controlled circulation, pressurized oil or gas-fired from 10 to 50 million Btu; coal-fired to 40 million Btu. Field-assembled units to 300 million Btu.



To 50,000 lb/hr . . . Type WCC—Shop-assembled. Utilizes waste heat from open hearths or chemical processes. C-E controlled circulation design obtains big boiler performance from space-saving units. Capacities to 50,000 lb/hr—and up, depending on waste heat conditions—with pressures to 450 psi and temperatures to 750 F. Capacities of field-assembled units are virtually unlimited.

shop assembled to 120,000 lb/hr capacity

Designed for Industry by UTILITY-BOILER ENGINEERS

C-E shop-assembled boilers are available for a wide range of industrial, commercial and institutional applications. They are produced by the same C-E engineers who design the world's biggest and most efficient utility boilers—with capacities to 4,000,000 lb/hr and pressures to 5,000 psi. For the most economical solution to *your* steam or high-temperature water problems, write to C-E, outlining your requirements. ***Catalogs are available.***

COMBUSTION ENGINEERING

General Offices: Windsor, Conn.
New York Office: 200 Madison Avenue, New York 16
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C-277-A

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 32 number 4 **October 1960**

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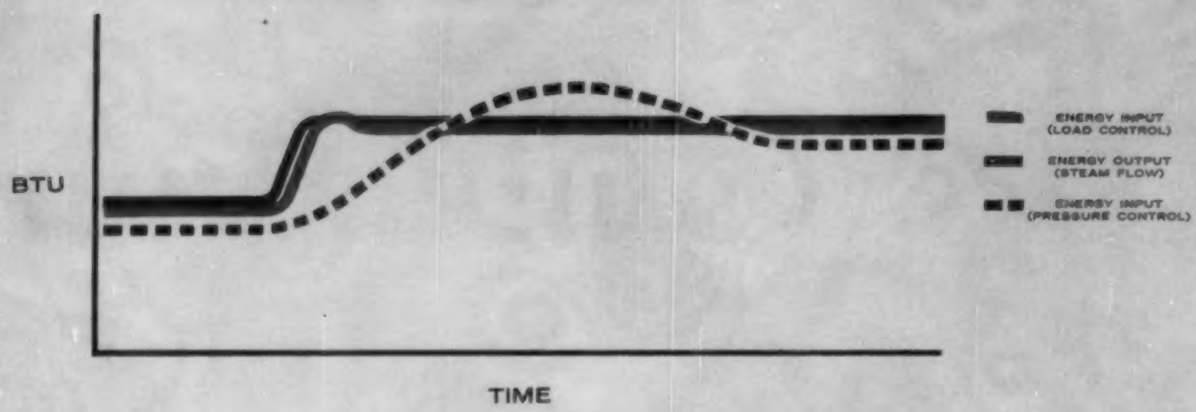
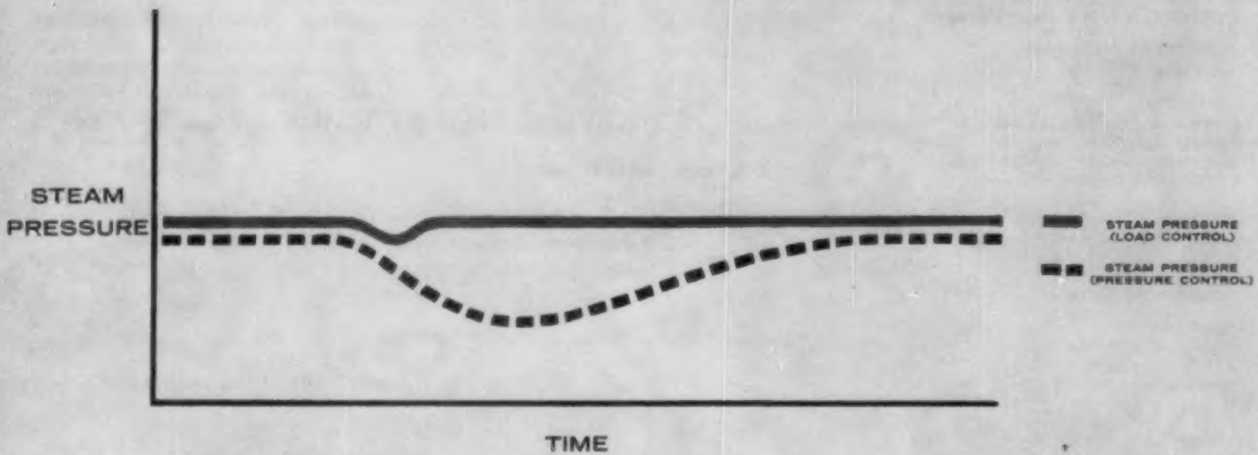
COVER PHOTO

Cutaway sketch of Swedish State Power Board's underground Stenungsund steam plant planned for an ultimate capacity of 700,000 kw.





Republic's patented electronic load control system quickly establishes new firing condition and rate of feedwater flow. Note that steam pressure varies a relatively small amount and for a short interval. Electronic load control establishes new energy levels much faster than steam pressure control systems. This high speed control results in improved stability and safety. Steam pressure is more accurately controlled, and a more efficient fuel-air ratio is maintained.

Republic Electronic Load Control Gives

Republic patented electronic load control instantly proportions fuel flow, air flow, and feedwater flow to a precise measurement of unit load. The moment a turbine steam inlet valve setting changes, Republic's load control changes the firing rate—long before steam pressure can vary. Minor pressure variations due to inaccuracy of fuel measurement impose a final adjustment to return steam pressure to the set point. Correct steam pressure is quickly restored because these small deviations from set point require proportionately short intervals for correction. Pressure swings are practically eliminated.

Accurate Control of Fuel-Air Ratio. Electronic load control makes it practical to control air flow directly from energy output or total steam flow. Fuel flow changes immediately with a change in steam flow, and only final trimming of fuel from steam pressure is required. The time interval between air flow change and fuel flow change is insignificant. Thus, with fuel flow and air flow changing simultaneously, air flow is proportioned directly to steam flow, and safe, accurate control of fuel-air ratio is maintained.

More Stable Feedwater Control. Feedwater flow is proportioned to the master load signal from the Republic load control system. It is also modulated by the drum water level. This provides the final minor correction that maintains the drum water level at the setpoint without excessive controller action.

PROOF OF PERFORMANCE

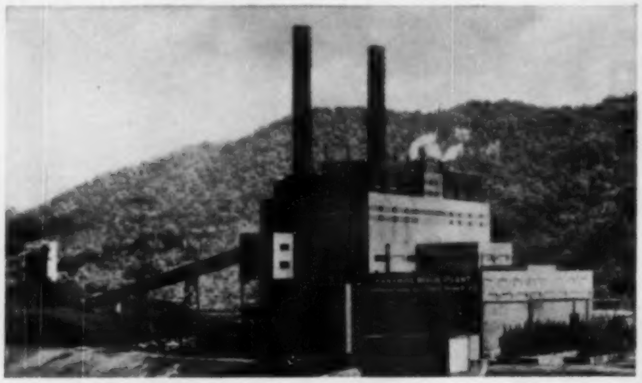
FPC's list of "most

finds Bailey users

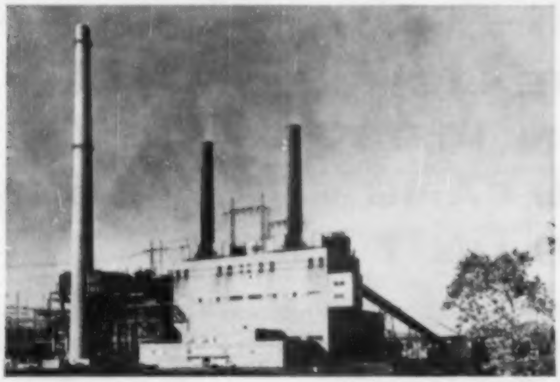
ST. CLAIR (The Detroit Edison Co.)—top 11, 1954-1958, averaging 9222 Btu/kwhr.

TANNER'S CREEK (Indiana & Michigan Electric Co.)—top nine, 1954-1958, first in 1956, averaging 9204 Btu/kwhr.

KYGER CREEK (Ohio Valley Electric Corp.)—top six, 1955-1958, first in 1955, averaging 9164 Btu/kwhr.



KANAWHA RIVER (Appalachian Power Co.)—top three, 1954-1958, first in 1954 and 1957, averaging 9128 Btu/kwhr.



MUSKINGUM RIVER (Ohio Power Company)—top five, 1954-1958, averaging 9216 Btu/kwhr.

BAY SHORE (The Toledo Edison Co.)—top ten, 1956-1958, averaging 9241 Btu/kwhr.

efficient plants"

as consistent repeaters

Thirteen of the 15 most efficient power plants on the Federal Power Commission's 1958 list use Bailey Meters and Controls.

For most of these plants, this marks the fourth or fifth consecutive year of top-ranked operating economy.

It is significant to engineers responsible for steam plant design and operation, that so many of these top performing plants are using Bailey Meters, Combustion Controls, Feed Water Controls and Superheat Controls.

Today, for breadth of product line, depth of experience and leadership in practical plant automation, no one can offer more to the power industry than Bailey. To apply Bailey's capability to your specific needs, check with the Bailey District Office or Resident Engineer listed in your phone book.

A145-2

instruments and controls for power and process

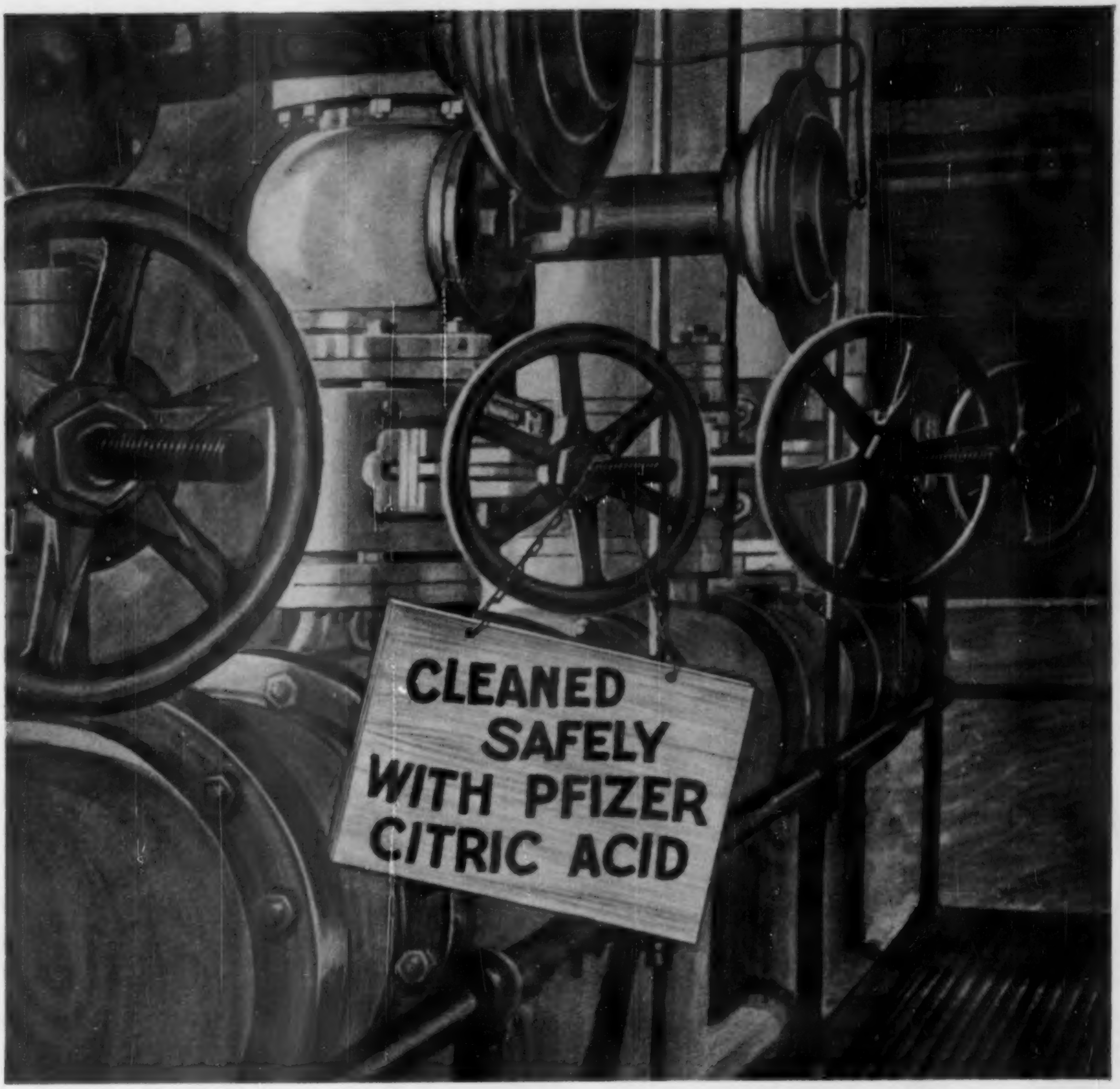
BAILEY METER COMPANY

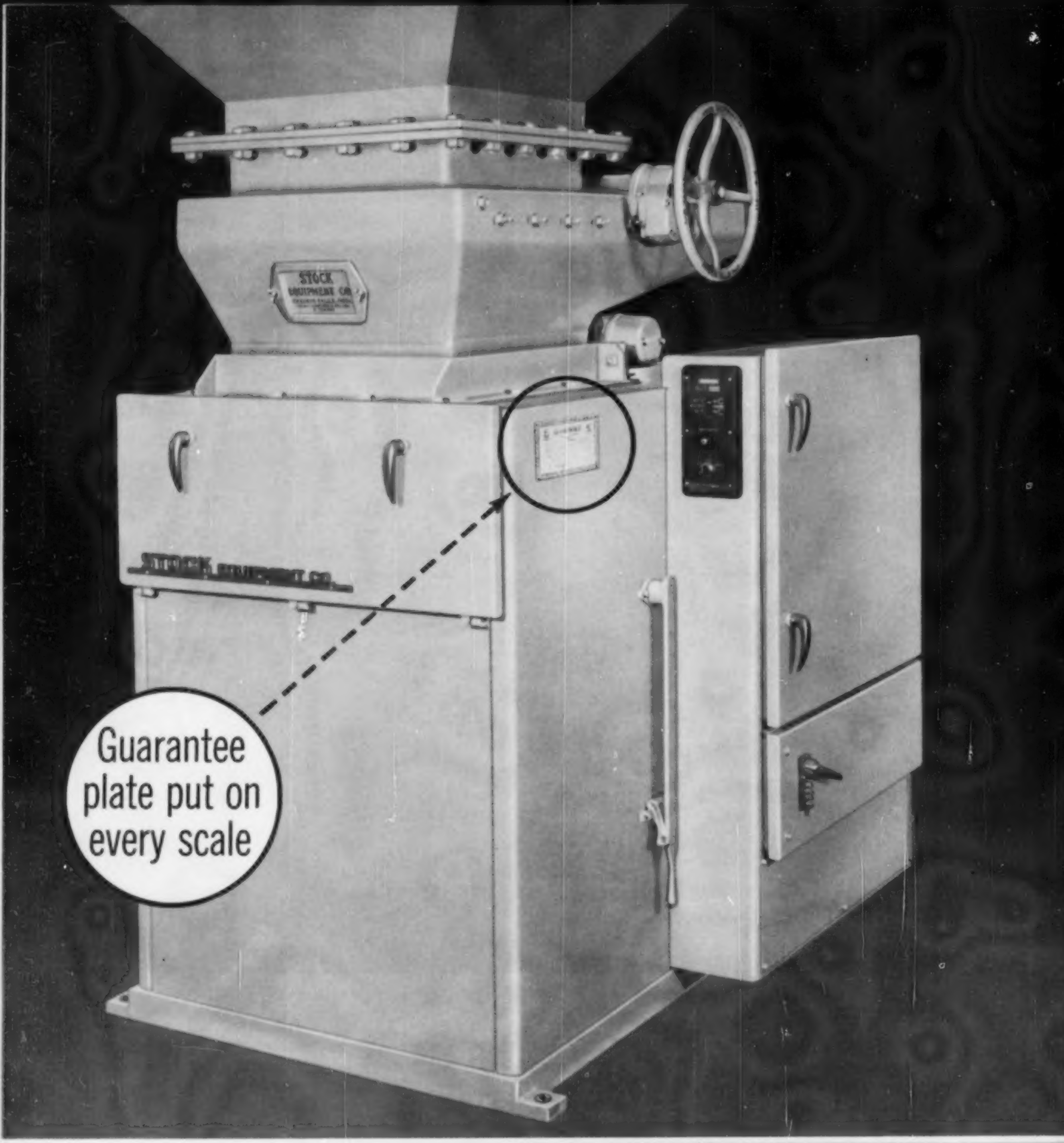
1025 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

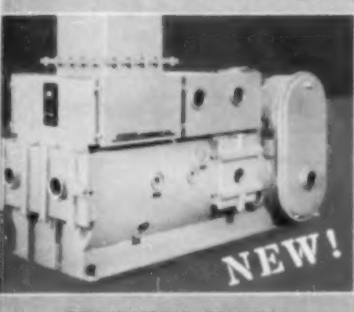
CLIFTY CREEK (Indiana-Kentucky Electric Corp.)—top five, 1955-1958, averaging 9155 Btu/kwhr.

PHILIP SPORN (Appalachian Power Co.—Ohio Power Co.)—top fifteen, 1954-1958, averaging 9378 Btu/kwhr.

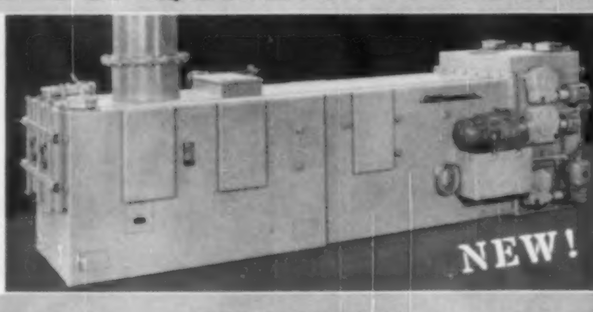

CLEANED
SAFELY
WITH PFIZER
CITRIC ACID



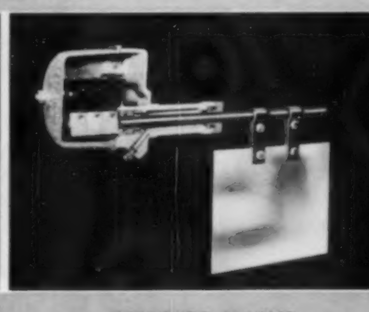
S-E-Co. QUALITY PRODUCTS



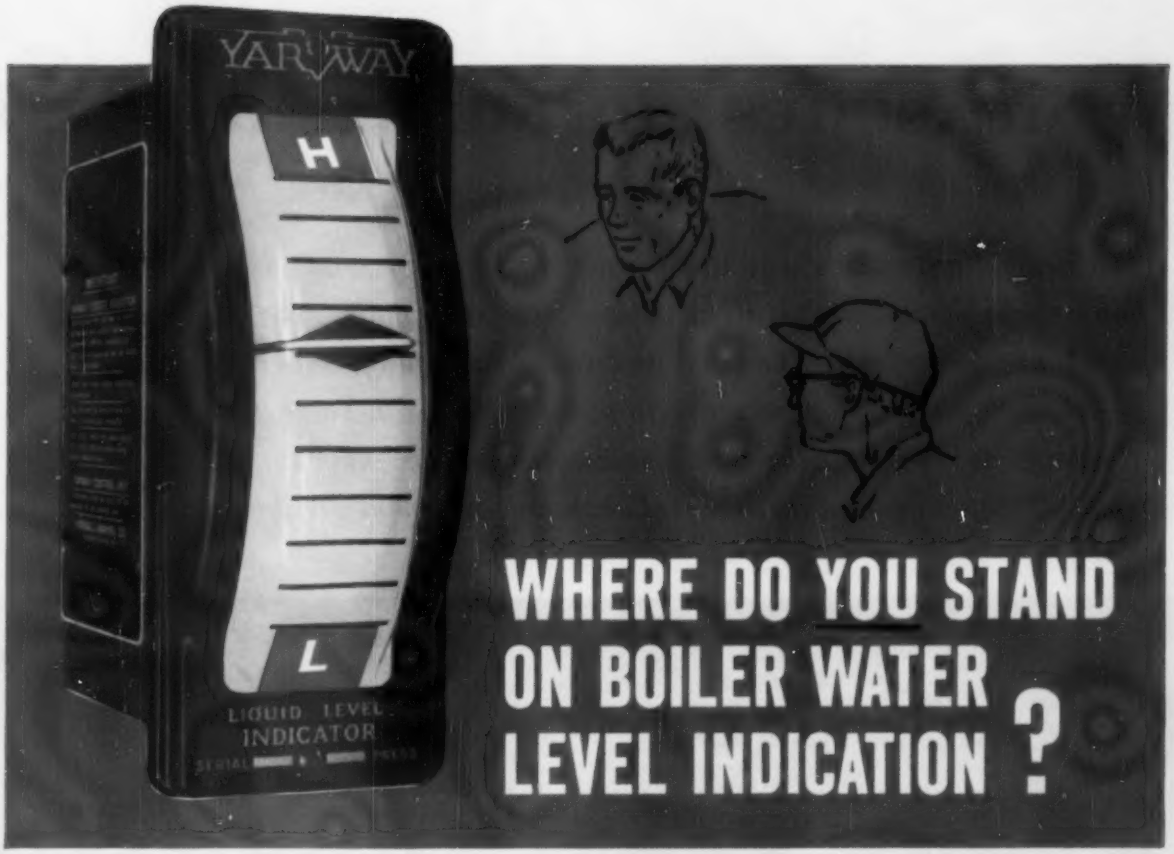
GRAVIMETRIC FEEDERS
Weigh and Feed



VOLUMETRIC FEEDERS
Feed Sticky Coals



STOPPAGE ALARMS
Two Types



Yarway Remote Indicators have "wide angle" visibility from multiple vantage points

Yarway Remote Liquid Level Indicators bring distant, often hard-to-see boiler level readings right down to eye level on the panel board or other convenient location.

No matter where you stand—at any point in a 180° arc, and from a considerable distance—the brilliant new wide vision dial makes viewing and reading easy.

Accurate readings because Indicator is operated by boiler water itself

Remote readings of levels in boilers (also feed water heaters and other heat exchangers) are instant and accurate because indicator *operating mechanism* is actuated by the varying head of the liquid itself, yet the *pointer mechanism* is never under pressure.

Fully approved under Boiler Code Case #1155

Under A.S.M.E. Boiler Code Committee ruling in Case #1155, two independent remote level indicators of compensated manometric type may be used as primary indicating elements instead of one of the two gage glasses required for boiler pressures 900 psi and above. When both indicators are in operation, one gage glass may be shut off but shall be maintained in serviceable condition.

Yarway Remote Liquid Level Indicators conform to this ruling and are used widely for primary boiler water level indication in plants operating at 900 psi and above.

All Yarway Indicators for service over 700 psi are temperature-compensated; pressure compensation available when desired. Use of controlled-temperature column on constant head chamber fully protects against system upsets.

If you would like a reprint of this Boiler Code ruling, just ask for Case #1155 reprint.

Get the full story on Yarway Liquid Level Indication for your plant. Write for new 24-page Bulletin WG-1825.

YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY
A MARK OF QUALITY IN STEAM ENGINEERING

TYPICAL USERS OF YARWAY INDICATORS FROM OVER 15,000 INSTALLATIONS

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MOBIL OIL COMPANY

UTILITIES
COMMONWEALTH EDISON
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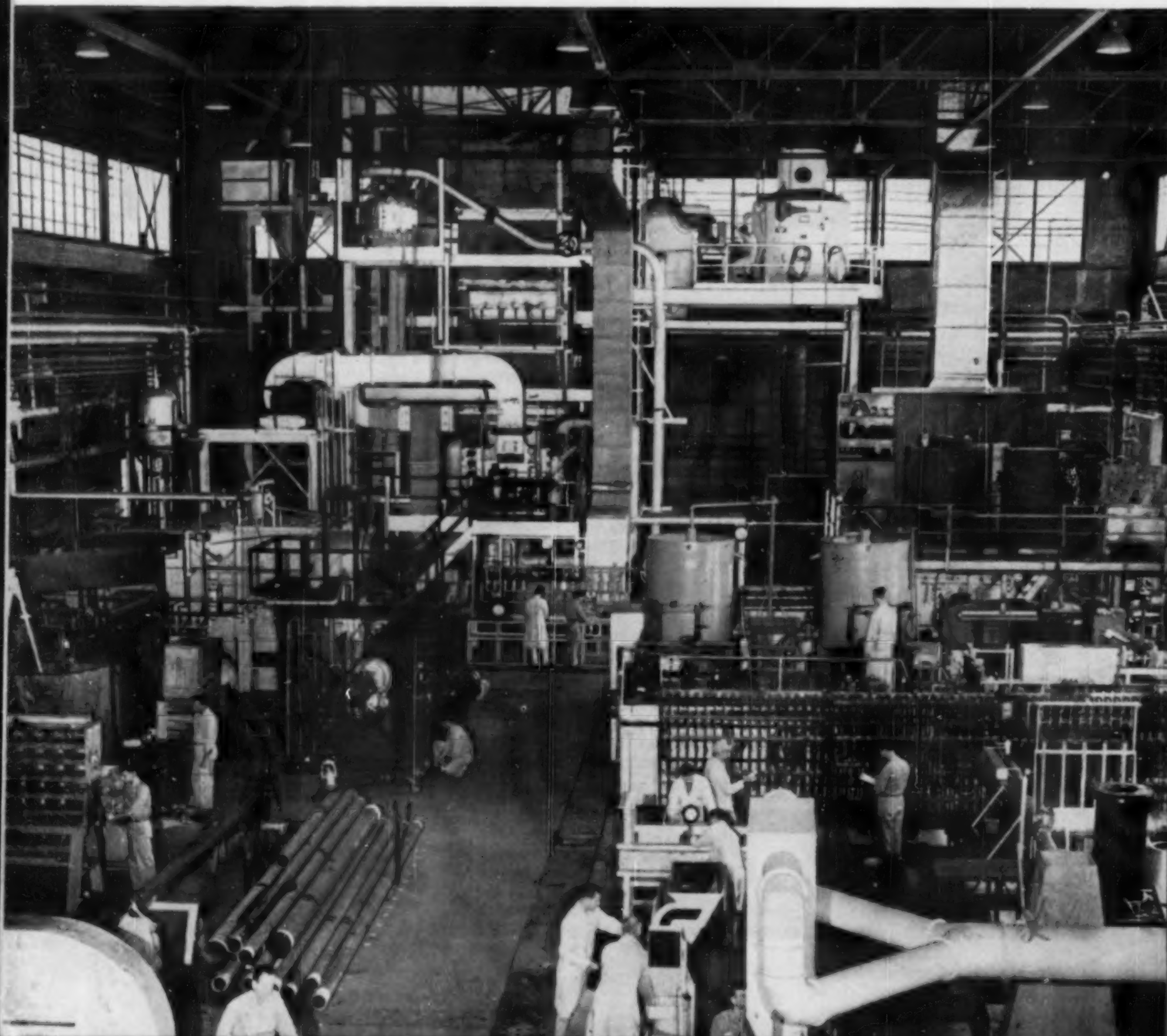
IOWA ELECTRIC LIGHT & POWER
NEBRASKA POWER
NEW ENGLAND POWER
ROCHESTER GAS & ELECTRIC CO.
PENNSYLVANIA ELECTRIC CO. (ERIE, PA.)
LOUISIANA POWER & LIGHT
POTOMAC ELECTRIC POWER CO.

C-E MEASURES THE MERITS OF IDEAS

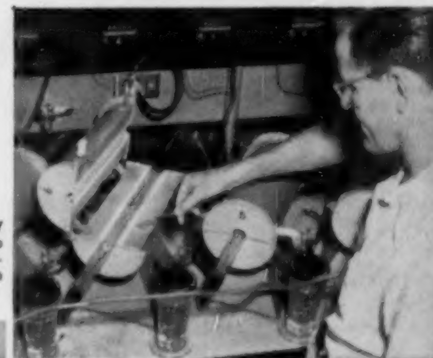
At Combustion, research guides the design of every product and is at the hub of every area of operation. It is a company policy, the premiums of which are paid for in the time and talents of many skilled and experienced specialists. Their purpose—to find a better way. Their goal—to enable Combustion to provide the most efficient, the most reliable and the most economical steam generating and fuel burning equipment available anywhere.



...WITH RESEARCH

Research activities at C-E range from studies of the nuclear characteristics of the atom and the combustion of fossil fuels to the development of methods and materials, the test of metals and the operation of test boilers and nuclear reactor systems. Research, knowledgeable and in depth, is your assurance that C-E products are thoroughly engineered, are dependable and are as modern as tomorrow.

THE KREISINGER DEVELOPMENT LABORATORY is used for the study of fuels and fuel burning systems, water, steam and combustion gases. It contains several test boilers, among them a large Controlled Circulation unit capable of operating at 2000 pounds pressure and a super-critical pressure boiler designed to produce steam at 5000 pounds pressure and 1200°F. This laboratory is one of eight C-E research facilities which, together, total more than four acres under roof.



THIS CHEMISTRY LABORATORY uses a battery of test furnaces to study the causes and effects of corrosive substances in combustion gases.

THIS ADVANCED CRITICAL FACILITY is one of two zero power nuclear reactors used by Combustion for test and experimentation.

THIS PHOTOELASTIC LABORATORY makes plastic models of various kinds of pressure vessels and loads them to simulate actual operating conditions. Using straining frames and polariscopes, it analyzes the stress patterns locked in the plastic to determine suitability of design.

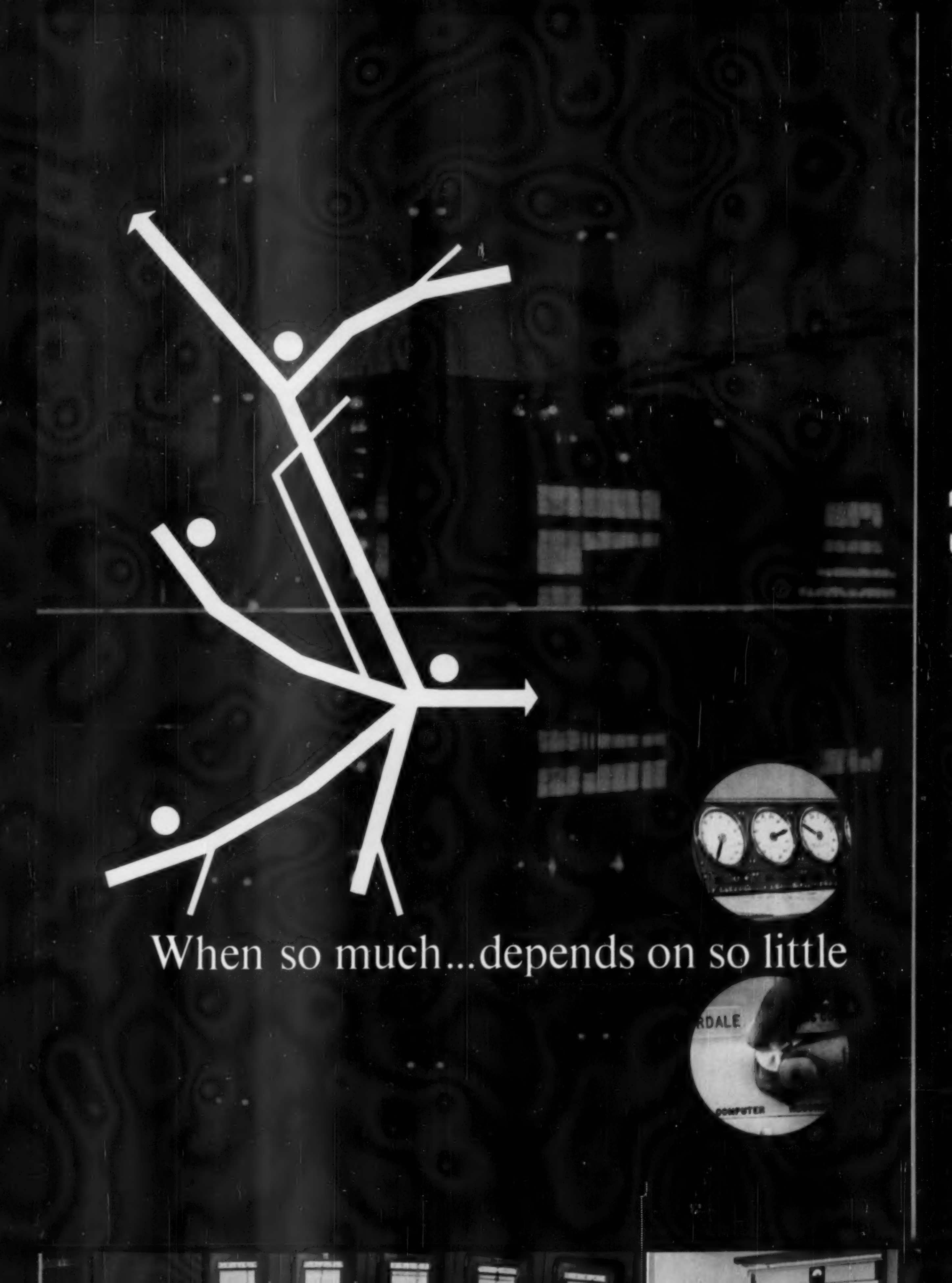
THIS METALLURGY LABORATORY tests material strength at high temperatures with these creep-rupture machines.

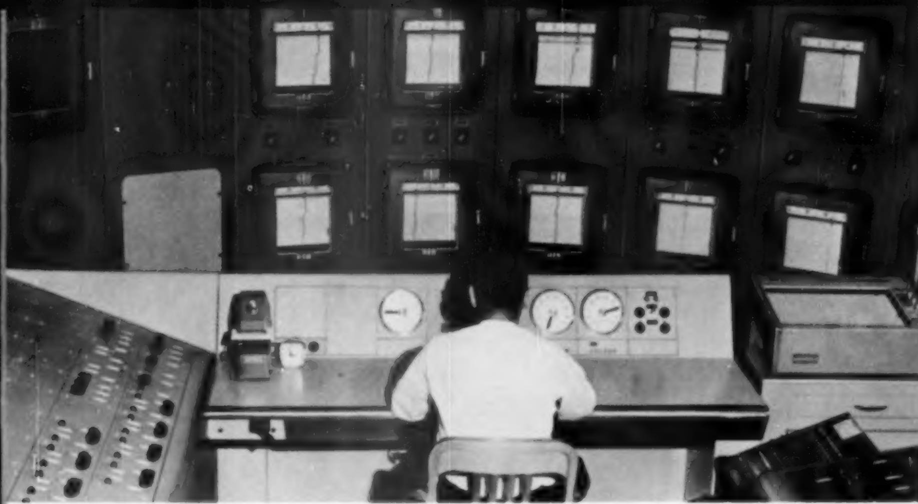
THE COMPUTER CENTER is used for many kinds of research work. C-E utilizes both digital and analog computer systems.

COMBUSTION ENGINEERING

General Offices: Windsor, Conn. • New York Offices: 200 Madison Ave., New York 16 C-281A

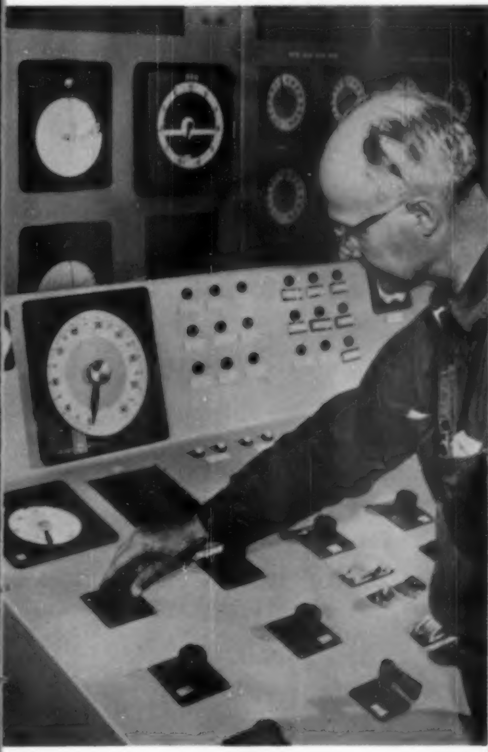
ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE.


When so much...depends on so little
COMPUTER



NEW DESIRED GENERATION COMPUTERS *provide operating flexibility, reliable control, accurate readout data, and graphic information on anticipated system conditions. Custom designed, L&N computers operate on nine American systems, control more than 11 million Kw on closed-loop basis.*

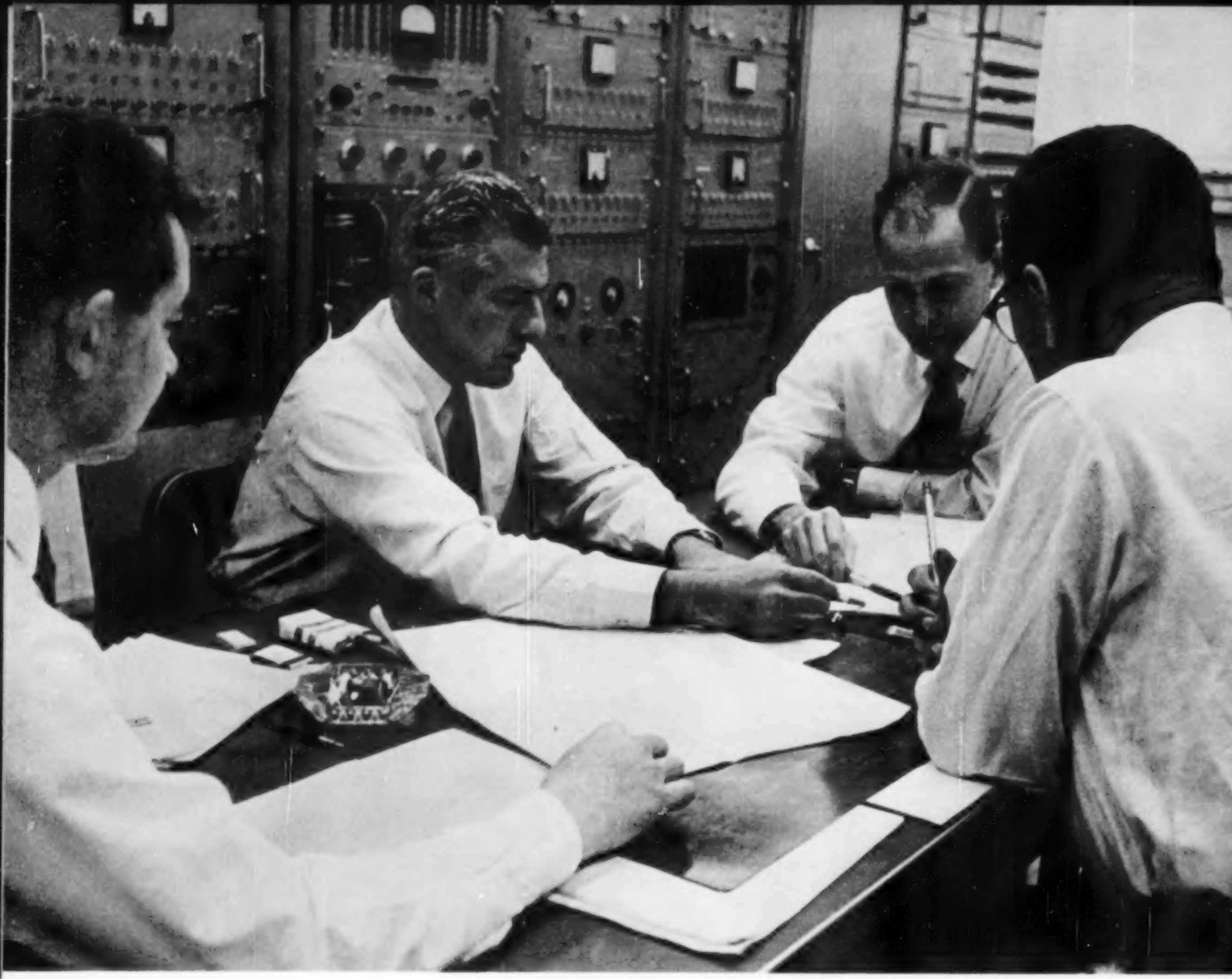
NEW LN 3000 DIGITAL COMPUTERS *provide performance computations, automatic plant control, automatic dispatch for an entire system. Designed to meet Leeds & Northrup specifications, the LN 3000 is expressly built for industrial applications.*



NEW L&N COMBUSTION CONTROL SYSTEMS *are installed on all six CE once-through Sulzer boilers in the U.S. Advanced Direct-Energy-Balance concept used by L&N engineers provides integrated control of boiler and turbine for optimum performance.*

NEW L&N DATA PROCESSING SYSTEMS *monitor boiler-turbine units . . . tabulate results on typewritten log sheets to facilitate orderly analysis of plant operation. Modular construction, solid-state circuitry, plug-in units make maintenance easy.*

NEW L&N REACTOR CONTROL MODULES *offer a more reliable system for nuclear plant control . . . facilitate maintenance with economy of operation . . . provide benefits of experience gained with modular packaging on world-wide L&N reactor installations.*



Operating problems are simulated in our R&D Computer Center.

When the time comes to decide . . .

. . . which computer or control is best for your particular requirements, you will doubtless look at alternate proposals, examine hardware, and study armloads of technical literature.

Increasingly, power company men are also looking at the control engineers with whom they'll be working, for they have found that, in the final analysis, the output of their computer or control can be no better than the power system know-how which is designed into it.

Talk with the men of L&N and, if at all possible, inspect their new R&D and production facilities in suburban Philadelphia. Look too, at the *results* of their work. You'll be glad you did.

For information on L&N computers and controls, see the power specialist at your nearby L&N Field Office, or contact 4907 Stenton Avenue, Phila. 44, Pa.

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MAJOR DRAFT SAVINGS

RIGHT FROM THE START

*
The "Q" Factor—the built-in Quality which provides trouble-free satisfaction and long life.

Utilizing a superior radial-tip blade wheel in the same stream-lined housing as the high-efficiency Buffalo Airfoil series, the Type "CR" Fan provides highly satisfactory performance in many punishing applications . . . at lower first cost. For example, its rugged construction and abrasion-resistant qualities make it a popular choice for handling fly-ash in power plants. Further, Buffalo Radial Blade wheels are available in varying widths and depths to meet most pressure-volume requirements efficiently. Write for Bulletin FD 205 and check the "Q" Factor* Features that make Buffalo Mechanical Draft Fans the best buy for your service.

- **Stable performance with or without fixed inlet vanes.**
- **Rising horsepower characteristic for efficiency at dampered ratings.**
- **Excellent for I.D. on stoker-fired or pulverized coal boilers.**
- **Use of smaller fan size possible on many direct-connected installations.**

AIR HANDLING DIVISION
BUFFALO FORGE COMPANY
Buffalo, New York
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.


'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.


'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.


'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.


Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

*Controls for a 1,260,000 lb/hr boiler are housed on a 36" wide console**

Centralized control space-saver

...the POWRMAG REMOTE CONTROL STATION

Easy to operate, and featuring front mounting and removal, the PowrMag Remote Control Station is ideal for the compact consoles demanded by centralized control. Here are some of the facts on PowrMag:

FULL STATION—size 2¼" x 5¼". As shown above, contains set point, bias or ratio dial, manual/automatic switch, manual control dial, output signal and null indicators.

HALF STATION—size 2¼" x 3⅛". With set point, bias or ratio dial, plus output signal indicator.

BUMPLESS TRANSFER—Simple adjustment of null-indicator provides bumpless transfer from Manual to Automatic or back. No operator memory is required. Output signal indicator shows valve or other control element position.

FRONT MOUNTING AND REMOVAL—Makes unit easy to check or change. AN-type connector, and 12-wire color coded cable makes it easy to interconnect system.

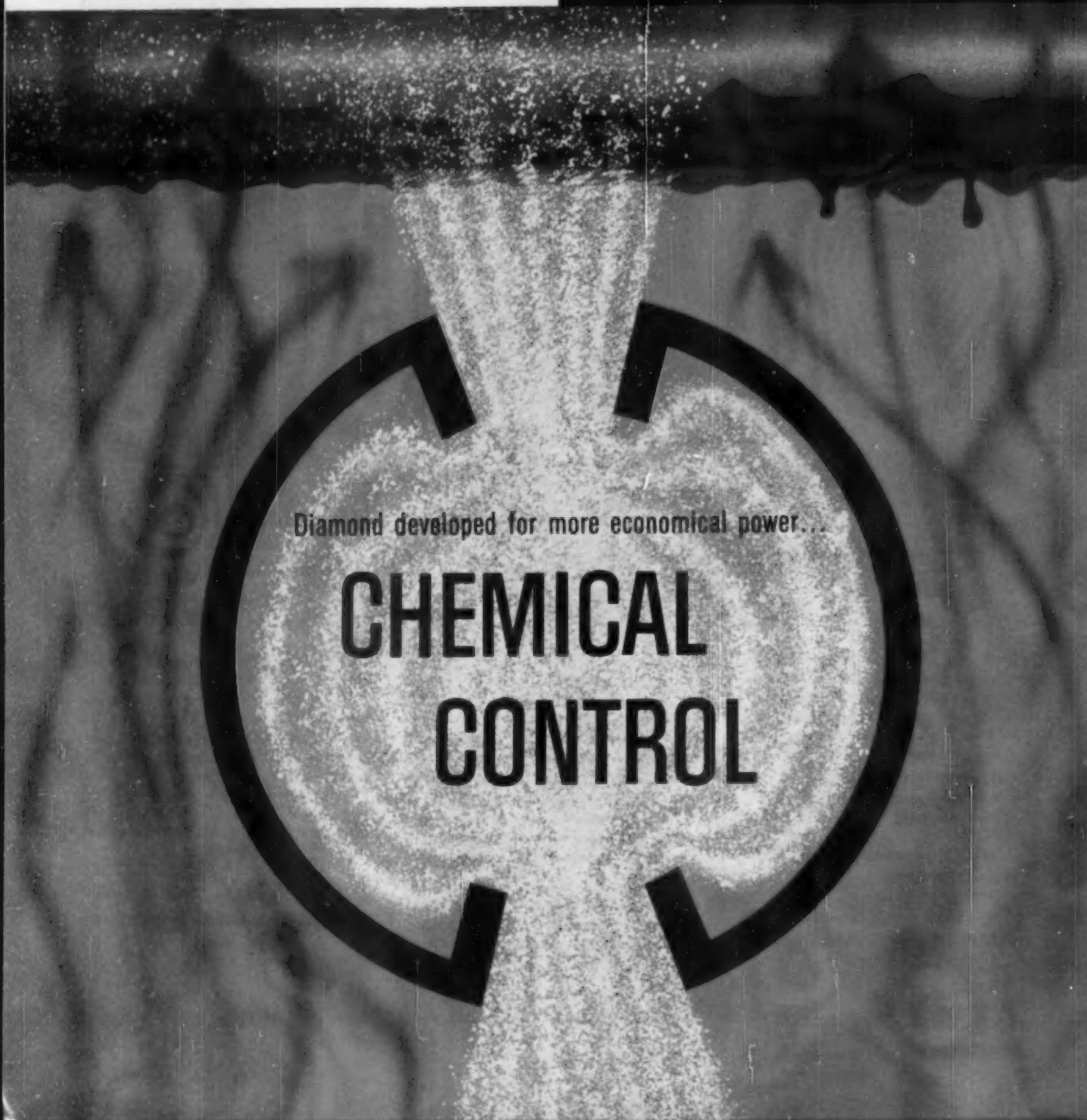
The complete system includes PowrMag Control Units and PowrMag Patchboards. Control units consist of operational magnetic amplifiers together with interchangeable reset, rate and other circuit packages to perform all control functions. Patchboards interconnect the system in any desired manner—no solder connections or terminal boards—all connections are made by special taper pins.

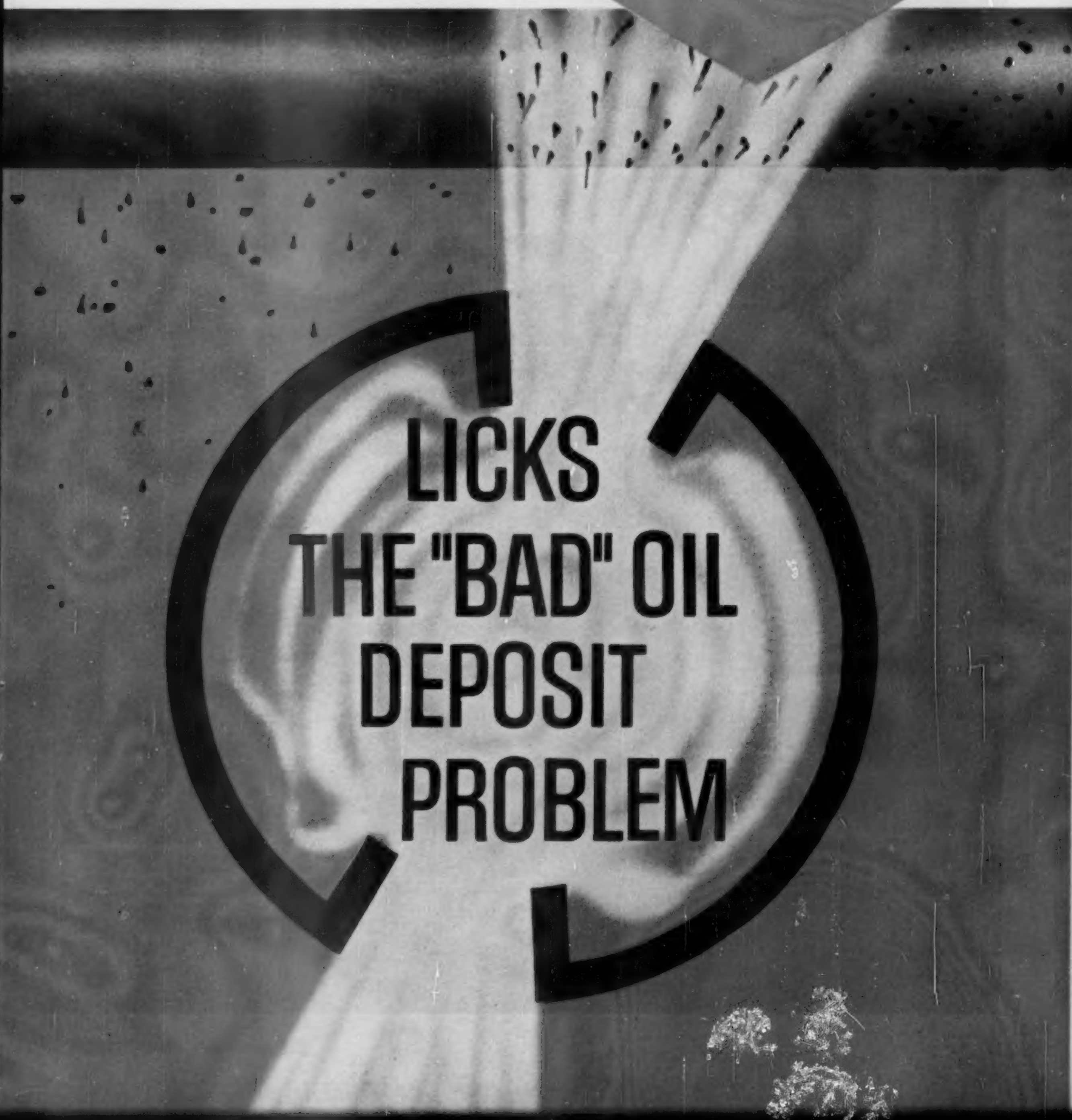
A letter or phone call will bring you more information on reliable, space-saving PowrMag. **Ask for Bulletin MSP-163.**

*Name on request

HAGAN
CHEMICALS & CONTROLS, INC.
HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO. • HALL LABORATORIES • BRUNER CORP.


Diamond developed for more economical power...
CHEMICAL
CONTROL


LICKS
THE "BAD" OIL
DEPOSIT
PROBLEM

ER COAL!

COAL IS ENERGY... producing low-cost kilowatt-hours for modern electrical living

As more and more Americans turn yesterday's household luxuries into today's necessities, electricity continues to be the greatest single force lifting our standard of living. In the last ten years our population has increased 20%. But the residential demand for electrical power during that time has risen 251%! For commercial and industrial use there has been a 150% increase. To satisfy this growing and boundless demand for dynamic energy, the electric utility industry has just about doubled its capacity every decade, all the while improving its fine record of giving more and more power for the consumer dollar.

Power companies are the biggest single user of coal. Nearly 70% of fuel-produced electric energy is generated by coal. Our country's five most efficient power plants, based on the 1958 report of the Federal Power Commission, operate 100% on coal.

In this booming energy market—and in other industries including steel making, process steam and heating as well — coal is the favored fuel. It offers the highest efficiency at lowest cost. It can match the stride of future consumption... is dependably, economically transported as needed by Chesapeake and Ohio's giant coal car fleet — and its abundant reserves can be counted upon for centuries.

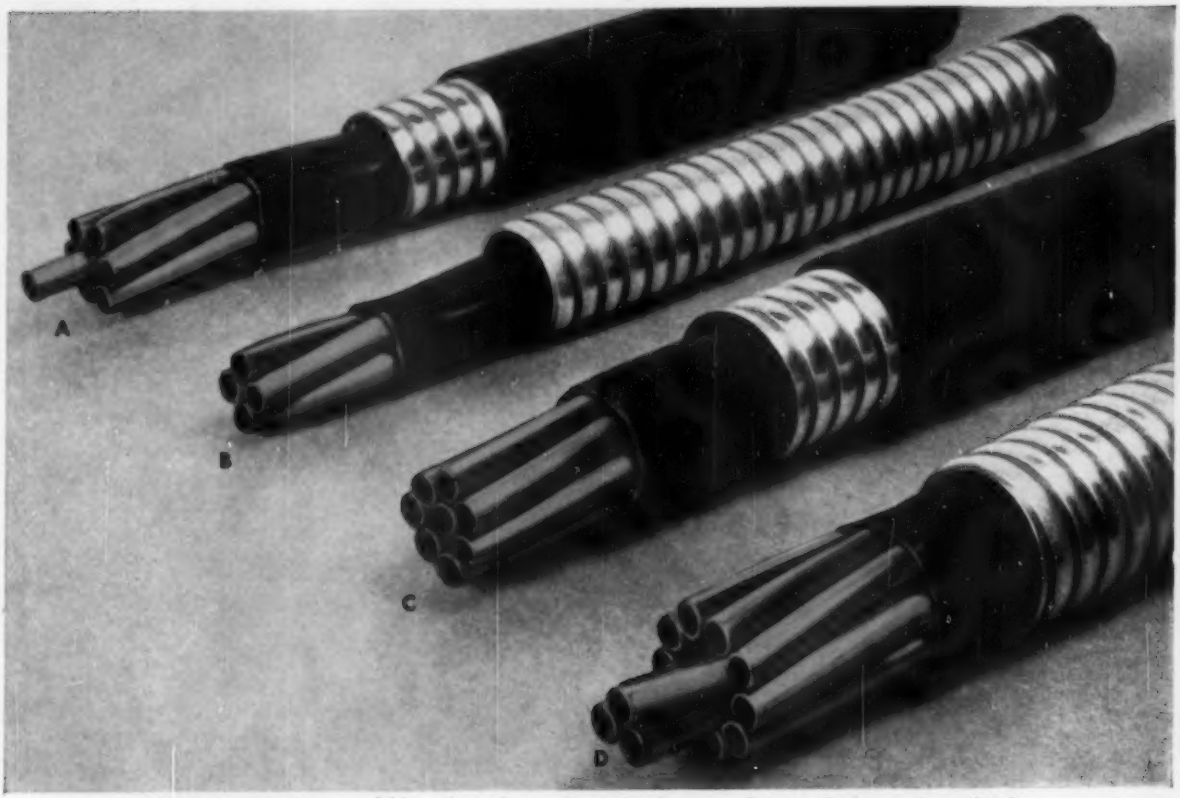
Chesapeake and Ohio Railway
TERMINAL TOWER, CLEVELAND 1, OHIO
Outstandability in Transportation

Coal is clean as well as economical for modern institutional heating. Advancements in handling and combustion equipment, electrostatic precipitators and other devices to prevent air pollution make coal the ideal fuel.

C&O Fuel Service Engineers offer free consultation in C&O's market areas on any problem of combustion, application, equipment or plant arrangement. Write to: R. C. Riedinger, General Coal Traffic Manager, at the address above.

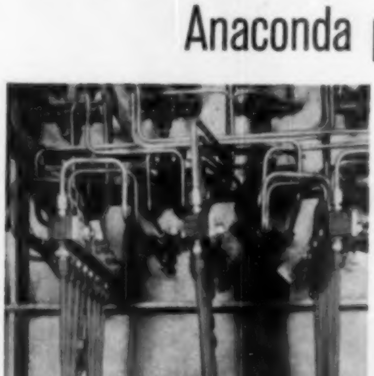
The 5100-mile Chessie Route directly serves over 300 mines in America's richest bituminous coal reservoir with the finest fleet of 68,000 coal cars. Specify C&O routing for dependable, efficient delivery.

CHESSIE SERVES THE COAL BIN OF THE WORLD



BAILEY ARMORTUBE is available with *A*, thermoplastic sheath over steel armor; *B*, thermoplastic sheath under steel armor; *C*, thermoplastic sheath over and under steel armor; or *D*, with just steel armor.

For its "Armortube" control system cables, Bailey specifies Anaconda precision copper tube in long coils



A TYPICAL INSTALLATION of Bailey Armortube in a large utility, indicating the large number of separate lines carried by two easily installed cables.

Armortube® flexible, armored, multiple-tube cable made by Bailey Meter Company, Cleveland, Ohio, has saved up to 40% of single-tube installation and maintenance costs in pneumatic, metering and control systems.

Armortube cable is available in lengths up to 1000 feet and in bundles of up to 19 individual ¼" O.D. copper tubes. Steel interlocking armor protects the tubes from mechanical damage and simplifies installation. In addition, various combinations of thermoplastic sheathing are available to provide further protection from moisture and corrosive atmospheres during and after installation.

CLEAN AND DRY. The copper tubes must meet rigid quality specifications, and Bailey has found that Anaconda copper tube consistently meets its requirements. Anaconda takes special care to see that inside surfaces are clean, smooth, and bright—free from dust, dirt, or metal chips which might interfere with the operation of delicate air and hydraulic circuits. Tube ends are sealed to keep out moisture and foreign matter during storage.

FLEXIBLE AND ACCURATE. Anaconda copper tubes are uniformly soft, highly flexible—for easy bending during installation. And they are accurate in size and shape.

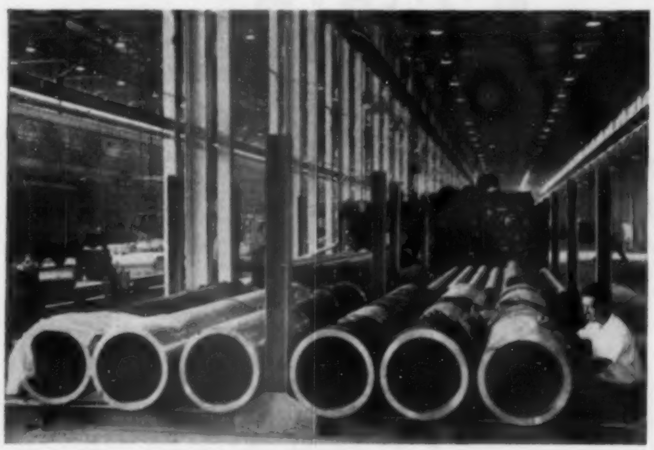
LONG LENGTHS. For applications such as instrumentation, Anaconda can produce copper tubing in coils up to 2200 feet for ¼" O.D.—up to 1400 feet for ⅜" O.D.—up to 1000 feet for ½" O.D.

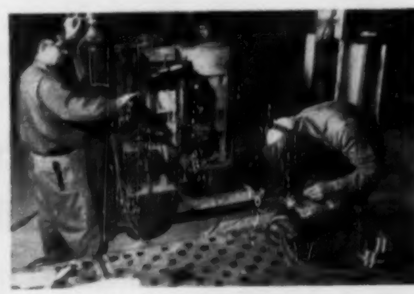
QUALITY TUBE AND CREATIVE TECHNICAL SERVICES. Whatever your requirements for precision copper tubing—instrumentation or capillary tubing, or restrictor tubes — Anaconda specialists can help you find the most economical way to do the job. For such technical assistance, see your Anaconda representative, or write: Anaconda American Brass Company, Waterbury 20, Conn.

ANACONDA®
INSTRUMENTATION TUBING
Anaconda American Brass Company

Now In Production at Williamsport

New manufacturing plant and headquarters of Kellogg's Power Piping Division—situated on a 50-acre site at Williamsport, Pa.





Above: Welding is a major phase of Kellogg's operations. Here, two thin-walled sections of stainless steel power piping are being joined by K-Weld—an inert gas-shielded technique of arc welding, patented by Kellogg, which assures long life.

Above: Raw materials bay, 40-ft. wide, extends the entire 900-ft. length of the plant. Piping and fittings are conveniently drawn from storage by overhead cranes and placed in the production line at any point in a planned manufacturing sequence.

Left: One of the new boring mills at Williamsport. Piping in machine is a stainless steel section—to be installed by Kellogg field erection specialists in the reactor sphere of a nuclear power station.

Left: Front entrance of Kellogg's new Headquarters Building. This ultramodern office building houses administrative, engineering, estimating, and accounting departments of the Power Piping Division. Sales offices remain at 711 Third Avenue, New York, N.Y.

The Promised Land Beyond the Facts....

DEAN C. J. FREUND

There are some engineers, as there are some in other professions, who are unhappy in their careers. These unhappy and discontented engineers often complain that there are no opportunities in the profession. What they really mean is that they do not become chief engineers, vice presidents and presidents of corporations; they are not moving up to the top.

Before Herman Weckler retired as the boss of the DeSoto Division of the Chrysler Corporation, I once asked him why there were not more engineers in the top jobs of the automotive industry. He replied, "Probably because they are engineers."

The top jobs, even in engineering, require men who can make decisions out beyond the boundaries of calculation, measurement and experiment. We say that we engineers work from facts, from quantitative experimental data. We are proud of it. But the really important decisions need more than facts and experimental data; they call for judgment, experience and willingness to take a chance. Should a Detroit corporation build a branch plant in Birmingham, or Hartford, or somewhere else, or at all? Engineers can assemble all kinds of data about power supply, land values, taxes, skills of the population, markets and much besides, but somebody still has to risk his reputation and his career, and decide whether and where the plant shall be built.

Most engineers don't like that kind of decision: "I'm an engineer. I can gather data and evaluate them, and I can complete calculations, even if they are complex. But I don't go in for guessing; that is none of my business." But somebody has to go in for guessing because engineering data do not go far enough to solve most industrial and business problems. There has to be somebody with the courage to extrapolate beyond the end of the curve—and hope that he is right.

This kind of extrapolation beyond engineering data is what boards of directors appoint administrative officers for. It is what they pay big salaries for. And because many engineers are afraid to venture into the territory where they can't take measurements, they fail to advance to the positions and the status to which they think they are entitled.

Engineers will come into their own as soon as they get all the facts, conscientiously apply all the facts that bear on the situation in hand, and then step out beyond the facts with courage in their hearts, and confidence that their judgment will be right.

C. J. Freund.

Dean of Engineering

UNIVERSITY OF DETROIT

This paper presents the results of some fairly recent tests, recalculated following the proposed code in which methods for determining a number of previously neglected losses have been outlined, and in which a change has been made in the basic definition of boiler efficiency.

Code Testing of Large Boilers-Input-Output or Heat-Loss Method?*

By J. A. BOSTIC† and W. F. LONG††

Cleveland Electric Illuminating Co.

FOR A number of years, boiler testing has been an important part of the testing program at the authors' company because up-to-date information about boiler efficiency is required for the economic loading of the generating system as well as in scheduling maintenance and evaluating boiler operation.

In the past, efficiency was determined by input-output measurements and the heat losses were used to determine the cause of poor performance. The unaccounted-for difference between input-output and heat losses was considered unimportant because it was thought to be made up of a number of small uncontrollable losses. Recently, however, significant numbers of operators are not equipping large boilers with accurate fuel-measuring devices, so the heat-loss method of determining efficiency has taken on a new importance. In recognizing this trend, the committee which is presently revising the Power Test Code for Steam Generating Units has expanded the section of the code on heat losses to include all of the heat losses which can be measured. In other words, they are trying to eliminate the unaccounted-for.

One purpose of this paper is to compare the results of the input-output and heat-loss efficiencies in light of this recent development in recognizing heat losses.

In reviewing the present code, the committee has suggested that a change be made in the definition of boiler efficiency. The second purpose of this paper is, therefore, to compare the old efficiency with the new efficiency —both by heat-loss and by input-output.

In order to have a common base for comparison, all of the comparisons in the main body of the paper are made from one set of test data. These data are from the most recent full-scale acceptance test at the authors' company, where the input-output efficiency was measured.

Boiler Testing in The Past

In 1924, at the authors' company, a large-scale boiler test(1)[1] was performed on one of the first large pulverized-coal boilers ever built. Both the pulverized coal and the feedwater were weighed with calibrated scales, and each test run averaged about 24 hr in duration. In general, the end of one run was the start of the next run; the test running almost continuously for about 27 days. Although the efficiency was based on the coal and water weights, the heat loss to the dry gas and the moisture loss were calculated.

Because of the great width of the boiler, flue-gas samples were taken at five points across each boiler uptake. Each point was sampled in turn from a collecting bottle which had been filling while the previous sample was being analyzed.

Shortly after this test, a five-point orsat was developed(2) so that five separate flue-gas samples could be analyzed simultaneously by one orsat operator. This orsat greatly improved the accuracy of flue-gas analysis from large boilers. A slightly modified, six-point version of this orsat is presently being used at the authors' company for all full-scale boiler tests and most air-flow meter-setting checks.

Through the years, a number of devices and schemes have been developed to eliminate the six-point orsat such as multiple-mixed samples and mechanical analyzers. So far, the most promising involves using an oxygen analyzer with a homemade device to permit rapid switching from one sample to another with the next sample purged. The orsat is still, however, the fundamental standard to which all of the other analyzers are calibrated, and mixed samples do not give as much information about the flue-gas distribution as individual samples.

[1] Numbers in parentheses refer to similarly numbered items in the List of References at the close of the article.

* Presented at the ASME-AIEE Power Conference, Philadelphia, Pa. Sept. 21-23, 1960 as Paper No. 60-PWR-5.

† General Supervising Engineer, Power Engineering Section.
†† Instrument and Control Engineer, Test Section.

A similar problem of averaged versus individual temperatures was solved by measuring individual flue-gas temperatures at five or six points across the duct rather than measuring an average temperature. From about 1930 to 1945, flue-gas temperatures were determined by measuring the EMF of five thermocouples connected in series spaced across the furnace and dividing by five. This gave a reasonably good average temperature, but it gave no indication of the temperature gradients across the furnace. Now individual thermocouples are used to obtain both the average temperature and the temperature gradient across the furnace.

During the early 1930's, a considerable amount of work was done to develop a formula for high-quality orsat solutions which would be relatively inexpensive, and yet would last through an extended boiler test in which as many as 200 samples might be analyzed. The results of this work were incorporated in an Edison Electric Institute report(3).

More recent developments in boiler testing at the authors' company are the use of a combination sampling tube and temperature probe,(4) the use of a multiple-point self-balancing precision potentiometer for temperature measurement, and improved coal-sample-preparation techniques. Recognizing the importance of good coal samples, a portable hammer-mill crusher was purchased so that 100 per cent of the gross sample can be crushed in a few minutes. The gross sample is kept in closed containers during the test. The coal is then crushed and immediately reduced, by splitting, to about two 1-qt samples. These samples are then sealed in polyethylene bags, and tagged for shipment to the laboratory.

Scope

This paper is limited to a discussion and analysis of the computations section of the proposed code, with particular emphasis on the change in the definition of efficiency and the newly recognized heat losses. The reason for the interest in these items in the proposed code is that they affect the unaccounted-for difference between the input-output efficiency and the heat-loss efficiency. If this unaccounted-for difference could be reduced to some negligible value, either method could be used for testing a boiler.

Heat Losses

The Power Test Code for Stationary Steam Generating Units PTC 4, 1946, lists the losses under two general headings: "Unavoidable losses" and "avoidable losses." The proposed code makes no such distinction since, for a particular type of loss, part of it may be in each category. With modern engineering advances, some losses may actually change from unavoidable to avoidable.

Grouping the losses from the present and proposed code in a similar form, the main difference is that the proposed code lists the following additional losses:

1. Sensible heat in the flue dust.
2. Heat in pulverized rejects.
3. Heat in cooling water.

Another change will be made in the ash-pit loss. The present code briefly mentions that the sensible heat in refuse can be determined only by heat balance with quenching water. The proposed code places more emphasis on determining the ash-pit loss. There will be a procedure for determining the various components of the ash-pit loss.

In the past, most boiler testers have neglected the ash-pit loss and the three losses listed. However, if the heat losses are to be used to obtain a true boiler efficiency, all of the losses must be considered. In the case of a 1,500,000-lb-per-hr boiler, such as our Eastlake No. 4 Unit, these four losses add up to about 0.4 per cent of the total heat input.

At this point it might be appropriate to point out one of the shortcomings of the heat-loss efficiency. Almost any error or omission will tend to increase the calculated efficiency. If the boiler tester is to approach the actual efficiency through heat losses, care must be taken to include all of the significant and applicable losses listed in the code, and it may be necessary to recognize new losses when a new or different type boiler is tested.

Efficiency Equations

Modern boilers employ numerous and various types of auxiliary equipment; therefore, the proposed code recognizes the heat produced by any of these auxiliaries which are inside the thermodynamic envelope. This heat is absorbed by the working fluid, the fuel, the flue gas, or the air supplied to the unit. In any of these cases, the heat produced by the auxiliary equipment is considered a heat credit. The proposed code considers the total heat input to the unit to be the sum of the fuel heat input plus the heat credits.

Since most of the auxiliaries are not intended as heat producers and are used to perform mechanical work, the argument may be raised as to whether all of this work goes into the boiler in the form of heat. There are two answers to this question: (*a*) Since the auxiliaries are inside of the thermodynamic envelope, energy enters the envelope, and, therefore, must be considered as part of the boiler input. (*b*) The auxiliaries all obey the first law of thermodynamics: Energy is neither created nor destroyed. The energy supplied to a mill, for example, must either be carried with the coal and air into the furnace, or is transferred to its surroundings by radiation

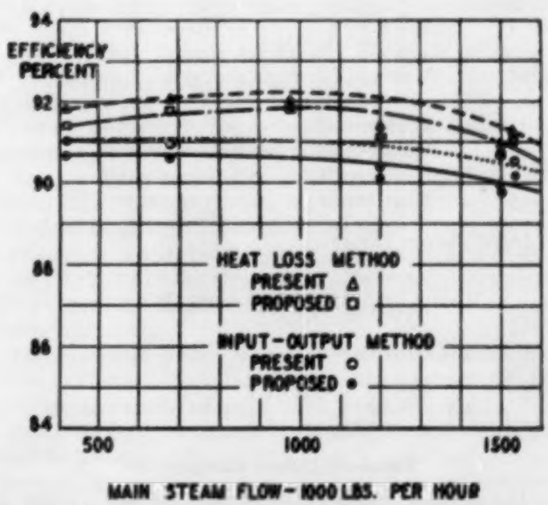


Fig. 1—Boiler efficiency comparison at present and proposed method

and convection. The radiation and convection loss must, therefore, include not only the boiler casing and ductwork, but also the foregoing auxiliaries which are inside of the thermodynamic envelope.

The efficiency as defined in the proposed code includes the heat credits in the total heat input. A brief derivation and example worked out for each method will best illustrate the differences between the two methods.

Following is a general heat balance around the boiler:

$$\text{Fuel heat input} + \text{heat credits} = \text{heat output} + \text{losses} \quad (1)$$

The existing code does not include heat credits, so efficiency is defined as

$$\frac{\text{Efficiency}}{100} = \frac{\text{heat output}}{\text{fuel heat input}} = 1 - \left(\frac{\text{losses}}{\text{fuel heat input}}\right) \quad (2)$$

The proposed code considers the heat credits as part of the input, and, therefore, defines efficiency as follows:

$$\frac{\text{Efficiency}}{100} = \frac{\text{heat output}}{\text{fuel heat input} + \text{heat credits}} = 1 - \left(\frac{\text{losses}}{\text{fuel heat input} + \text{heat credits}}\right) \quad (3)$$

From the third equation, we can see that the newly defined input-output efficiency is *lower* than the old. Note that since the losses are negative and only about 10 per cent of the heat output, the heat-credit term will *increase* the heat-loss efficiency, but only about $^1/_{10}$ as much as it decreases the input-output efficiency.

Example 1: Present code definition of efficiency using simulated test data:

Assume: Fuel heat input = 100 measured
Heat output = 90 measured
Heat losses = 9 measured

Input-output efficiency:

$$100\left(\frac{90}{100}\right) = 90 \text{ per cent} \quad (4)$$

Heat-loss efficiency:

$$100\left[1 - \left(\frac{9}{100}\right)\right] = 91 \text{ per cent} \quad (5)$$

Example 2: Proposed Code definition of efficiency:

Assume: Fuel heat input = 100 measured
Heat output = 90 measured
Heat credits = 1 measured
Heat losses = 9 measured

Input-output efficiency:

$$100\left(\frac{90}{100+1}\right) = 89.1 \text{ per cent} \quad (6)$$

Heat-loss efficiency:

$$100\left[1 - \left(\frac{9}{100+1}\right)\right] = 91.09 \text{ per cent} \quad (7)$$

Boiler-Efficiency Comparison

The authors' company tested Eastlake No. 4 boiler by the input-output method and by the heat-loss method. This steam-generating unit consists of a controlled-circulation radiant boiler with twin water-cooled balanced-draft furnaces, a convection superheater, a convection reheater, an economizer, three Ljungstrom air preheaters, and eight bowl mills. The guaranteed capacity of the unit is 1,500,000 lb/hr main steam flow with 2400 psi pressure at turbine throttles, and 1050 F main and reheat steam temperatures.

The results of this test have been recalculated to show how the additional heat losses and the change in the efficiency equation affect the results. Table I shows the full-load heat losses and efficiencies with the unaccounted-for calculated three ways.

TABLE I—COMPARISON OF HEAT LOSSES

	Original Test Calculation Per cent	Original Test Calculation with Newly-defined Losses Per cent	Proposed Method Per cent
Heat Losses:			
(1) Unburned carbon	0.39	0.39	0.39
(2) Dry flue gas	3.78	3.78	3.77
(3) Moisture in fuel	0.58	0.58	0.58
(4) Moisture from hydrogen	3.69	3.69	3.68
(5) Radiation and convection	0.26	0.26	0.26
(6) Ash pit		0.35	0.35
(7) Moisture in air	0.11	0.11	0.11
(8) Atomizing steam	...	...	...
(9) Unburned hydrogen	...	...	...
(10) Carbon monoxide	...	...	...
(11) Unburned hydrocarbons	...	...	...
(12) Sensible heat in flue dust	...	0.03	0.03
(13) Pulverizer rejects	...	0.005	0.005
(14) Cooling Water	...	0.004	0.004
Total Heat Losses	8.81	9.20	9.18
Efficiency:			
(1) Heat-loss Efficiency	91.19	90.80	90.82
(2) Input-output Efficiency	90.53	90.53	90.29
Unaccounted for	0.66	0.27	0.53
Miscellaneous Data:			
(1) Heating value of fuel......			12,154 Btu/lb.
(2) Heat Credits..............	31.7 Btu/lb. coal fired, or 0.26%		

1. The original calculation.
2. The original calculation plus four additional heat losses.
3. The proposed code calculation including the four extra losses.

Fig. 1 is a curve of efficiency versus steam flow for this unit, showing the original input-output and heat-loss efficiencies as well as the same curves recalculated following the proposed code.

The results on Table 1 show that the additional losses which were not originally calculated help to reduce the unaccounted-for. The next step, changing the efficiency equation, shows we still have a significant unaccounted-for that was previously hidden by the heat credits.

Conclusions

There are still several unanswered questions about boiler testing. This paper is only a progress report describing the probable effect of using the proposed code to test a large coal-fired utility boiler.

We believe the new efficiency equation and the newly defined losses are more realistic, and will give a more

nearly correct result than the existing code. This does not mean that the end is in sight because we still have an unaccounted-for difference between the input-output efficiency and the heat losses. In fact, this unaccounted-for is still approximately the same size as before.

The reason for this paradox is that the proposed code has added two items to the heat balance. One is the additional losses which reduce the unaccounted-for. The other is the heat credits which increase the unaccounted-for.

It would be wrong to ignore these items just because they tend to cancel each other. With some types of boilers, these items may not cancel each other, and, under some abnormal conditions, these items may explain deviations of efficiency from its normal or predicted value.

We believe that the input-output efficiency is, at present, the right efficiency. We feel that if enough work is done to find the unaccounted-for, it will be found not in the input-output efficiency, but in the heat losses. At present, boiler testers face a dilemma. Fundamentally boiler efficiency is defined by the input-output method. We say this is the correct method for measuring efficiency. Input-output boiler testing requires accurate coal and water-measuring equipment, which is difficult to find and expensive to install. On the other hand, heat-loss efficiency testing is, with the possible exception of flue-gas analysis equipment, easy to find, relatively inexpensive to install, and fairly easy to use. The only problem is that it does not, as yet, give the correct answers.

The Future of Boiler Testing

More work should be done to find the last few heat losses. To do this, boiler owners will have to cooperate with boiler manufacturers to develop theories, develop procedures, and apply these in tests to find the losses.

At present, we believe the ash-pit loss and the radiation and convection loss should be more thoroughly investigated. Recent work on the ash-pit loss indicates this is a significant loss. More work should be done to verify the preliminary test work.

On the other hand, the radiation and convection loss has been investigated in the past, but now with more modern boilers and their extensive use of auxiliary equipment, this loss should be reinvestigated. This loss should include:

1. The boiler casing.
2. Superheater, reheater, and economizer casing.
3. The air preheater, all of the auxiliaries, piping, and duct work in the thermodynamic envelope.
4. Any other equipment which will contribute to or reduce the radiation and convection loss.

As with some of the other losses, it is difficult to measure all of the radiation and convection loss. Any errors or omissions will tend to give a lower value than the actual loss. Another phase of this problem is the artificial convection loss created in a large boiler house by the ventilation equipment. In order to keep air temperatures around the boiler down to some reasonable value, large utility-type boiler rooms are ventilated. These large quantities of air sweeping up over the boiler casing probably increase the convection part of the radiation-convection heat loss. The ABMA curve may not include this artificial convection loss. In any case, this whole area could use more work to bring it up-to-date.

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(2) "Apparatus for Gas Analysis," U. S. Patent 1719864, Carl D. Zimmerman, July 9, 1929.
(3) "Standard Method for Flue Gas Analysis," Power Station Chemistry Subcommittee of the Edison Electric Institute, Publication No. D5, July 1936, pp. 4–7.
(4) "No Trouble with This Homemade Thermocouple," by R. G. Schuerger, *Power*, August 1956, p. 132.

Correction Notice:

In the May issue of COMBUSTION *on page 43 the American Power Conference paper presented by D. O. Thompson and M. Zar contained the following error:*

One of the striking conclusions resulting from the coring of concrete chimney shells was the discovery that the brick linings on negative pressure chimneys did *leak gas. In transposing this piece of information the word "not" was used, resulting in an erroneous statment. We thank the authors for calling this to our attention and regret that we allowed so much time to elapse before inserting this correction notice.*

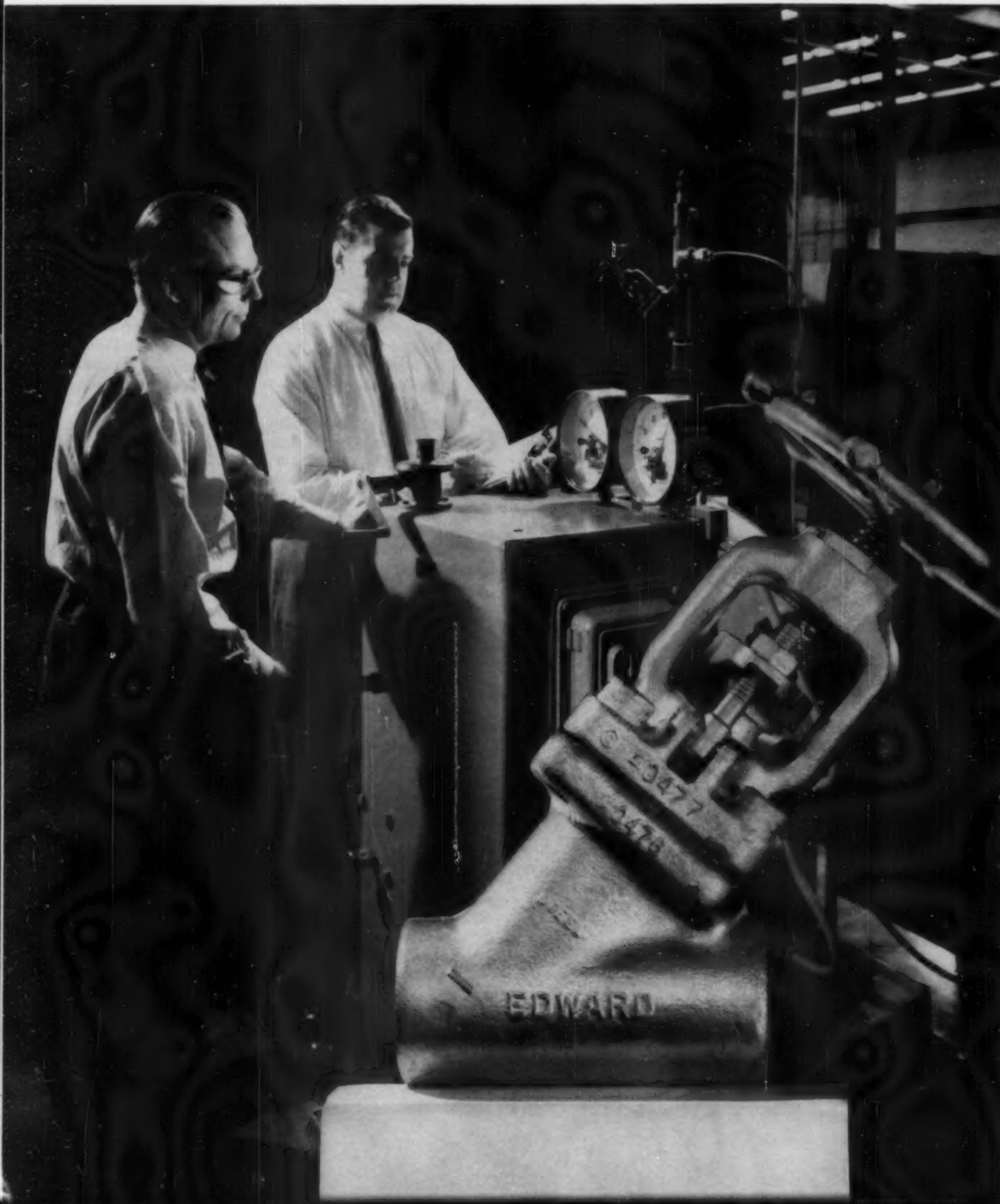
Key Associations Reorganize Personnel

The American Society for Testing Materials by action of its Board of Directors elected **Thomas A. Marshall, Jr.** executive secretary, effective October 15, 1960. Mr. Marshall is currently senior assistant secretary of the American Society of Mechanical Engineers.

As executive secretary of ASTM, Mr. Marshall will head a staff which supports a Society of 10,500 members and 6000 additional committe members. Through its organization of some 85 technical committees, ASTM devotes its efforts to the stimulation of research and to the development of standard specifications and methods of test for materials.

The American Boiler Manufacturers Association with offices in Newark, New Jersey, have just appointed **Max O. Funk** assistant manager. Mr. Funk was graduated from the College of Engineering of New York University. Prior to his appointment he was with Combustion Engineering, Inc. in the capacity of servce engineer, service superintendent, chief engineer of the industrial division and as a technical consultant.

The Story of Edward Research



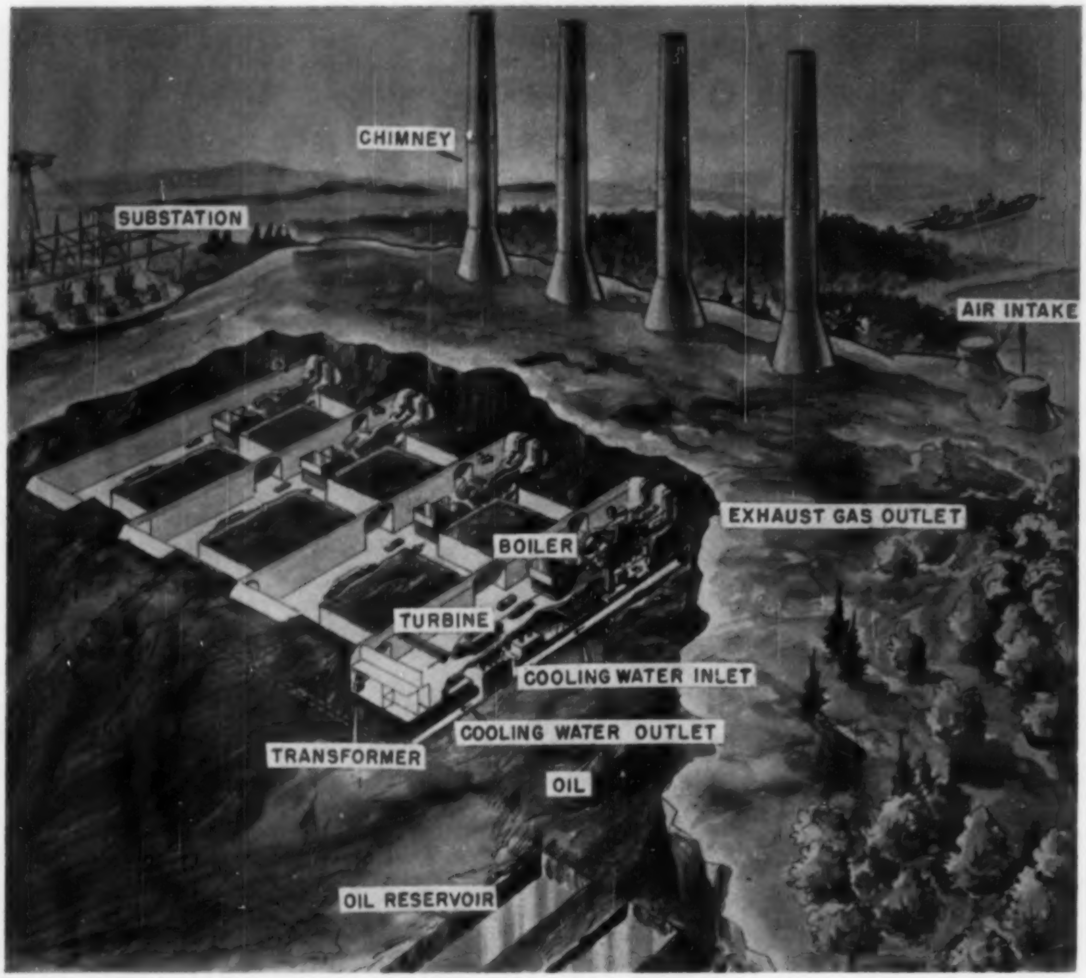


Fig. 1—Cutaway view of Swedish State Board's new Stenungsund under-ground steam plant shows four machine bays, each with a ventilation section, boiler, high and low pressure turbines, generator and transformer. Note also the use of sea water to cool the tunnels.

Unique Swedish Steam Station in Operation

By HOLGER LUNDBERGH*

An eventual 700,000 kw steam power plant to occupy roughly one half acre well underground at a cost of $40 million will double the State Power Board's thermal power capacity in less than a year's time.

THE FIRST unit, of 150,000 kw, of the Swedish State Power Board's new underground Stenungsund steampower plant on the west coast, north of Gothenburg, has already gone into operation. Another unit of the same size should be completed this autumn. When fully built to its eventual rating in excess of 700,000 kw towards the end of this decade, Stenungsund will be Sweden's largest power plant in all categories—compared with 400,000 kw for the new Stornorrfors hydro-power station—and probably the biggest underground steam-power plant in the world.

Initial construction work on the Stenungsund station began in 1955. The idea was then to build only two units of 100,000 kw each, but as the planning proceeded

* American-Swedish News Exchange.

it was found possible to increase the effect through new designs, the introduction of intermediate steam reheating. Further it was also decided to dimension the plant for a further two units.

The new station is entirely encased in the solid bedrock of a mountain just outside the community of Stenungsund, Fig. 1. The only visible parts are the smokestacks, towering 280 ft above the ground and 490 ft above sea level, and the main switchgear plant, Fig. 2, which feeds the 130,000 volt power into the grid network.

The projection and construction of the Stenungsund plant was carried out by the State Power Board, while the mechanical equipment is being supplied by a number of leading Swedish industries. These include STAL (de Laval-Ljungström), which has contributed the largest turbine plant ever built by the company, Svenska Maskinverken, which are responsible for the record-breaking boilers, and Svenska Fläktfabriken, which designed the extensive ventilation equipment. ASEA has delivered transformers, switchgear plant, while Nordarmatur has supplied the high pressure valves, just to mention a few of the collaborating domestic companies.

The construction work for the new plant required the removal of 1,570,000 cubic yards of rock for the four underground machine halls, access tunnels. Each of the two halls in the first building stage has a length of 410 ft, a width of 69 ft, and a height of 98 ft, while the remaining bays are somewhat larger. Cement consumption totaled 16,000 tons, reinforcement iron 3500 tons, and steel structure, excluding boilers, 3000 tons.

Each machine hall forms a separate unit and includes a ventilation section, boiler, high and low pressure turbines, generator, and transformer. The huge volume of air required for ventilation is evident from the fact that the equipment has a capacity of 1260 tons of air per hour. The unit for separating solid particles in the smoke treats 908,000 cubic meters of gas an hour with a purification degree of 90 per cent. Sea water is used for cooling the 9800 ft tunnels having a capacity of 40 cubic meters per second.

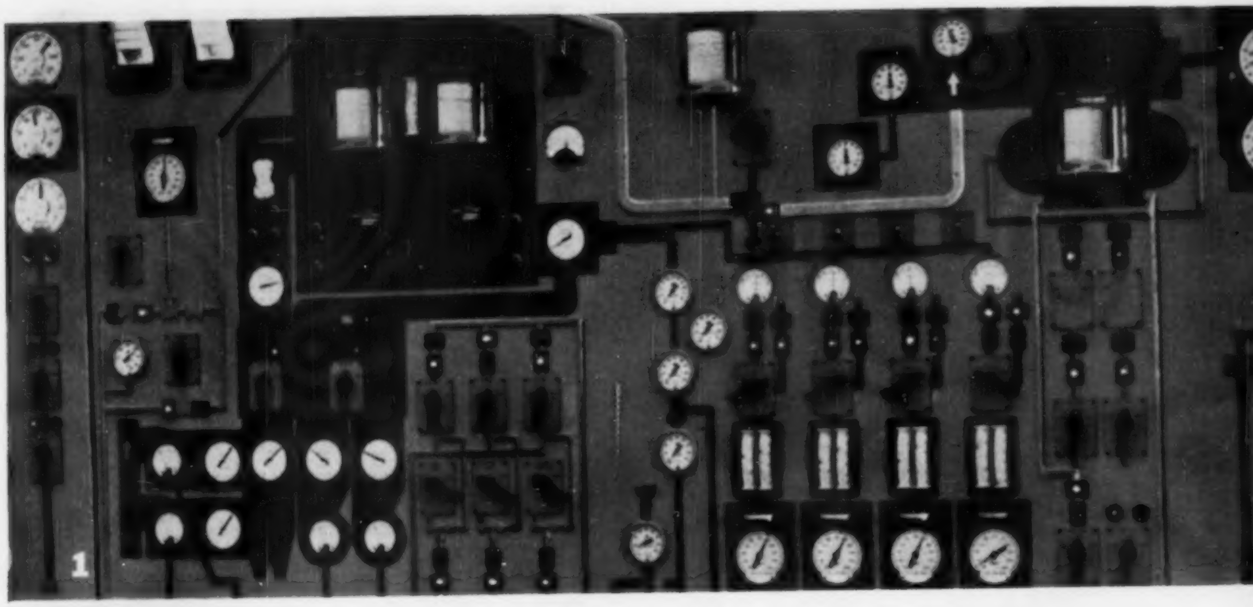
Fig. 3—Machinery bay No 1 with 150,000 kw capacity beginning with the boiler, far end, to higher pressure and medium pressure turbines, foreground.

Fig. 2—Main switchgear, right foreground, and smokestacks, background, are all that show above the ground level.

Each boiler consumes about 35 tons of oil, of the Bunker C type, per hour, and the peak temperature at the 16 burners is 1700 C. The volume of steam in the boiler and heater sections amounts to about 450 tons an hour at temperatures of up to 530 C. The boilers are of the horizontal type and provided with conventional components such as preheater and economizer. From the boiler the steam is conducted to the high-pressure turbine and back again for intermediate heating, before being fed into the low-pressure turbine. This system is claimed to guarantee improved operational economy, although it entails a somewhat longer starting-up period.

The STAL turbo-generators, of which the high-pressure unit has a rating of 39,000 kw and the low-pressure unit one of 111,000 kw, are of essentially new type. Both are designed for a speed of 3000 rpm and for the first time in Sweden hydrogen has been introduced as a cooling medium. From the generators, the power is transmitted, over aluminum rails, encased in steel tubes, to the main transformer. A joint control room, situated between the two machine halls, serves the first and second units, for entirely automatic operation.

The oil required for the operation of Stenungsund is discharged at a special harbor, which has been built about a mile from the plant itself. It consists of a pier 325 ft long and 45 ft wide and an access bridge of almost equal length. Tankers of up to 65,000 tons can be accommodated on either side of the pier. From the harbor, which was built by the contractors, Skånska Cementgjuteriet, the oil is pumped into tanks blasted out of the rock. Great care has been taken to prevent spill oil from polluting the sea water in this area, which is a much-frequented seaside resort.



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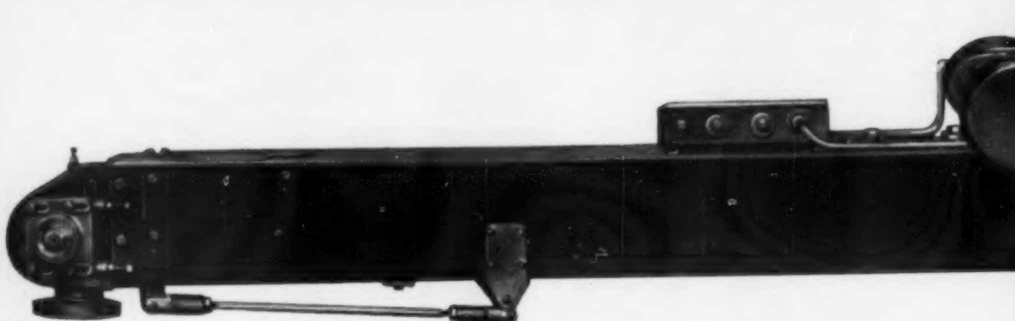

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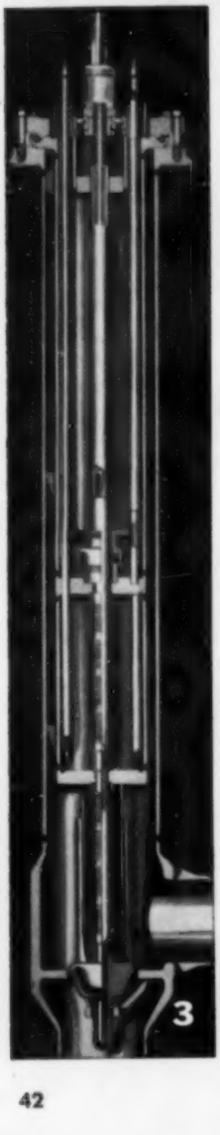

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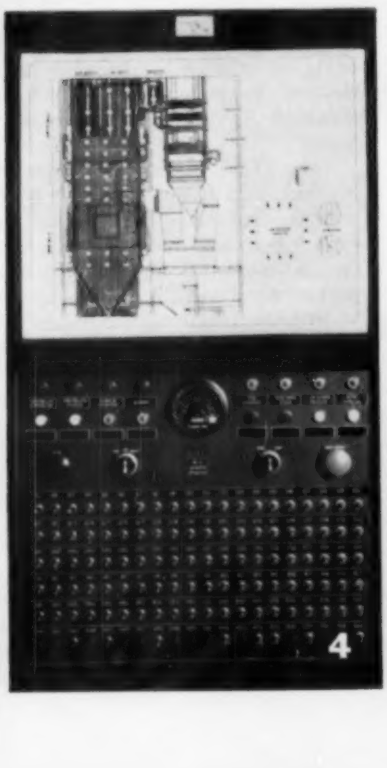

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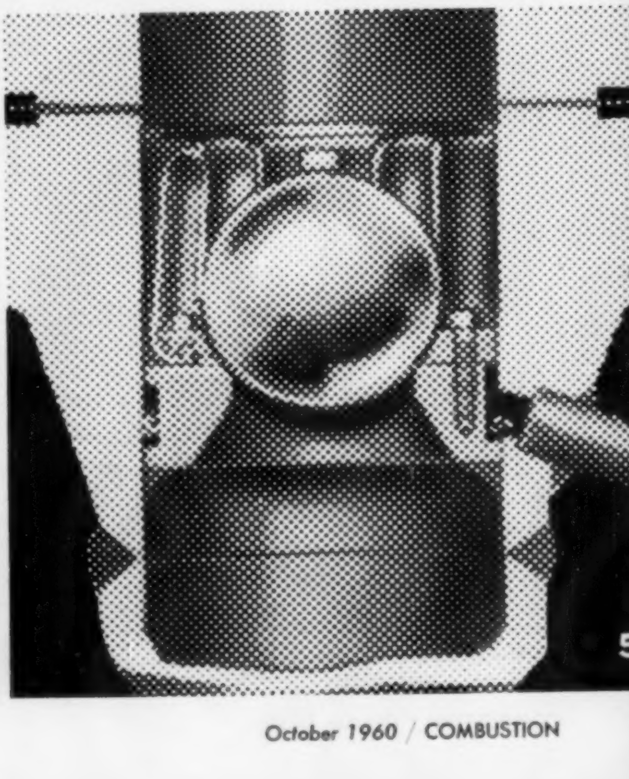

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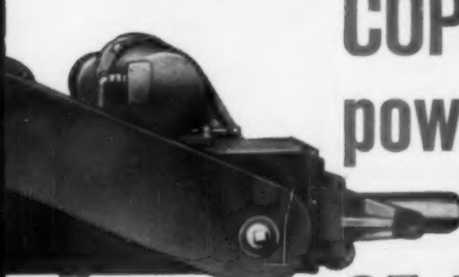

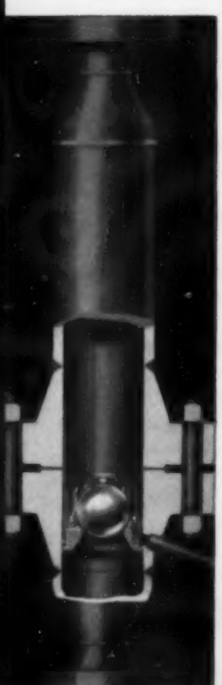

Considerable headway is being made in the acceptance of non-destructive testing methods for power plant construction and maintenance. If properly used, these techniques constitute a valuable tool in determining the quality of workmanship (in acceptance tests of equipment) and the survival outlook of installed equipment which may be exposed to mechanical wear, erosion or corrosion. They find further application in locating obstructions which may form in pipe lines or other equipment.

Non-destructive Techniques in Power Plant Inspection

PETER W. SHERWOOD

Research Engineer*

THE TERM "non-destructive testing" calls for more exact definition. It covers obviously methods of examination which do not harm the sample or item under investigation. But, within this wide scope, a further definition becomes possible by exclusion.

There are numerous physical tests for determination of specific properties—density, conductivity, specific heat—which are carried out by non-destructive means. These methods, however, call for preparation of samples of specific size and shape, and they are outside the proper scope of this discussion.

Also not included are "proof tests," in which only defective samples are destroyed. In these methods, the specimen—or even the entire equipment—is subjected to conditions which exceed normally expected operating conditions in severity. Typical of this class are pressure tests and tensile strength measurement.

The most obvious method of non-destructive testing is visual inspection. This is, however, obviously confined to exposed surfaces, and will also not be considered here.

Finally, there is a group of tests in which a very small sample serves, so small indeed that it does not generally impair the equipment under study. However, the methods are not, rigorously speaking, non-destructive.

Thus, non-destructive testing, in strict parlance, may be said to be a method of inspection which is applicable to both exposed and unexposed areas of equipment and which may be carried out on the equipment proper, rather than on a mere sample, without in any way harming or changing its physical characteristics.

Power Plant Practice

In power plant practice, several basically different methods within this province find useful application They may be broadly classified as follows:

A. Electric and Magnetic Testing Methods (involving measurement of such properties as capacitance, conductivity, electromagnetic inductance, etc.).
B. Radiographic Methods (X-rays, gamma-rays, fluoroscopy, etc.).
C. Ultrasonic Methods.

These major classes are supplemented by a miscellany of diverse methods, among them liquid penetration test, vibrational tests, etc.

The most important determinations which may be effected by these means are: measurement of thickness, detection of cracks at or near the surface, build-up of foreign material (rust, obstructions, etc.), detection of flaws and leaks.

The attraction of non-destructive testing is that measurements can be effected in areas which are inaccessible by other means, and that the tests can frequently be carried out on site and while the equipment is in operation.

The methods are always indirect, so that a proved correlation must exist between the measured property and the information which is desired. This is a prime prerequisite without which no suitable method can be developed. No one method can be applied to measuring a particular property in all situations. Before a non-destructive inspection is chosen in any but a routine installation, careful evaluation must be made of the special problem at hand, including considerations of kind of material, geometric features, operating conditions, etc.

Non-destructive testing is properly limited to properties which are of practical importance in operating

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service, for the methods—and their development—tend to be too costly for universal application where other approaches will suffice. Furthermore, the testing engineer must be sure that the measured property is the only source of possible trouble. For example, several factors may combine to weaken a part in service. It would be pointless and dangerous to measure only one of these factors and rely on the findings, lest the presence of other weakening effects predominate and cause failure which might have been prevented by due attention to all the aspects involved.

Most non-destructive tests depend on the flow and measurement of energy in one form or another. Taking account of the widely divergent means at the engineer's command to apply this basic requirement to different situations, McMaster (1)* finds that there are five essential features common to most non-destructive tests:

1. Supplying a suitable form and distribution of energy from an external source to the test object.
2. Modification of the energy distribution within the test object as a result of its defects or variations in the natural properties which correlate with serviceability.
3. Detection of the change in energy properties by a sensitive detector.
4. Indication or recording of the energy measurement from the detector in a form useful for interpretation.
5. Interpretation of the indication, and judgment of the corresponding serviceability of the test object.

Unless an adequate solution exists for each of these five requirements, a method of non-destructive testing may not be considered to be reliable or useful.

In the following discussion, we shall illustrate some of the major techniques which have been evolved in the field of non-destructive testing, and which are of actual or potential interest in the construction and operation of power plants.

A. Electric and Magnetic Testing Methods

(1.) Measurement of Thickness

In this field, Hanstock (2) recognizes five significant methods, involving measurement of capacitance, transformer efficiency, magnetic force, inductance, and resistance.

The first-named of these, **the capacitance method,** measures the change in frequency of high-frequency oscillations which is brought about in a resonance circuit containing a capacitance as the distance is varied between the plates of the condenser. By making the test unit itself a part of the condenser it is possible to determine the thickness of a non-conducting layer on a metal base (such as aluminum oxide on aluminum). The method is of limited application, largely because of mediocre accuracy, but it has been used to advantage in high-temperature work.

The **transformer method** may be used with high sensitivity to measure the thickness of magnetic metal or of coatings on magnetic metal. In the latter case, the test piece is made an (unwound) leg of a transformer core. The efficiency of the transformer decreases directly with increasing thickness of the non-magnetic layer. The thickness of magnetic metal may be measured by taking advantage of the fact that penetration of the magnetic flux decreases with increasing frequency of currency. The relative penetration at defined conditions is measured into the test sheet and into a reference sheet of known thickness. This transformer method is a particularly convenient means to measure the thickness of material to which access from only one side is possible.

A **magnetic method** for determining the thickness of non-magnetic deposit on a magnetic metal determines the force which must be applied to detach a calibrated magnet from the surface. The procedure is affected by many variables, including the production history of the test piece and it is therefore only of very limited usefulness.

The impedance of a coil is affected by the thickness of a non-conducting layer with which it may be in contact (if the coating is supported on metal). This property is used in the **inductance method** of measurement. However, the procedure is applicable only to very flat surfaces since flaws in the contact between coil and surface affect the readings significantly.

Of more extensive applicability is the **resistance method** for measuring metal thickness from one side. The electrical resistance between two points on a metal surface is a direct fraction of the metal's thickness (it is proportional for flush pieces; calibration is necessary for thicker metals). The equipment for this measurement is simple and relatively inexpensive. Allowance must be made for the temperature of the system, and care must be taken that the test area is not too near the edge of the plate where significant deviations from the calibration curve will occur.

(2.) Detection of Cracks

A magnetic method which finds extensive application in the detection of cracks at the surface of iron and steel depends on the preferential attraction of magnetic particles to flaws at or near the surface of the test piece to which a magnetic field is applied. The particles are usually applied as a dry powder, but are also available immersed in oil. The area of the flaw can then be detected visually by the local accumulation of the small particles which are pretreated, e.g., by a fluorescent or just a simple dye.

The method is of particular value in finding surface cracks in castings, forgings or welds. The same procedure has also been applied to test the quality of welds on plain and stainless steels (2). It has been observed that the permeability of such welds is high if the workmanship is good. If, therefore, a magnetic field is applied to the weld and magnetic particles are dusted on, a high degree of particle retention speaks favorably for the weld's quality.

Several flaw-determination methods take advantage of the irregularities produced in the flow of surface electrical currents by the presence of superficial cracks. A fairly simple application of this phenomenon is the **direct-current method**. Here, a current is made to flow between two electrodes attached to the surface

* Numbers in parentheses refer to similarly numbered references in the Bibliography at the close of the article.

under examination, and the potential drop is measured. As the electrode system is moved from point to point on the surface, the potential drop remains approximately the same unless a flaw is present at some point between the electrodes. In that event the resistance, and with it the potential drop, of the system is increased. It thus becomes possible to pinpoint the imperfection in the material.

The direct method calls for very intimate contact between the electrodes and the metal surface, an evident drawback. An alternative electrical technique for determining flaws near the surface of metal is the **eddy-current method**. In this approach, a surface is probed by passing over it a coil carrying alternating current. If the coil is kept at a constant distance from the metal (and not too close to the edges), its impedance will remain constant except in the case of a crack or flaw.

B. Radiographic Methods

Techniques involving the passage of very short waves through the material under examination encompass today the most extensively applied area of non-destructive testing. In this field, too, the most important advances of the last decade are registered and very active research continues.

The important advantage of radiography is that it permits measurement at considerable depth within the test material. To permit such penetration into the interior, it is necessary to use waves of high frequency. Customarily X-rays or gamma rays are employed. The principal difference is the source of the radiation. **X-ray examination,** which has been available for a much longer time and has become standard in numerous industrial acceptance tests, depends for its radiation on the emission from metal (usually tungsten) which is bombarded with electrons by applying a high electric potential to an evacuated tube. **Gamma rays** are the spontaneous emanation of certain isotopes; in non-destructive testing methods, the use of cobalt 60 and iridium 192 as a convenient source of gamma rays has, of late, come to the fore.

The wide scope of tests which may be carried out by radiographic methods has been illustrated by Van Horn (3) for the specific case of determination of discontinuities in cast and wrought products. Van Horn lists the following possible measurements:

1. *Gas:* Gas holes; gas porosity.
2. *Shrinkage:* Shrinkage cavity; shrinkage porosity or sponge (non-ferrous alloys), micro-shrinkage (magnesium base alloys).
3. *Heterogeneities:* Foreign materials; segregations.
4. *Sharp Discontinuities:* Hot cracks; cold cracks; cold shut.
5. *Miscellaneous:* Surface irregularities, misruns; core shift.
6. *Weld Discontinuities:* Incomplete joint penetration; undercut; porosity; slag; cracks.

Beyond that, there is a wealth of applications in the inspection of materials other than cast and wrought metals. In power plant work, probably the most important use of radiographic methods is made in the inspection of welds and determination of **wall thickness** of equipment.

The principle of radiographic measurement involves a determination of the extent to which the rays are absorbed in the course of passage through the test piece. Such absorption is a direction function of the thickness of metal through which the radiation must pass. The presence of a flaw in the path of the rays decreases the total metal thickness when compared to an adjacent flawless path. The outline of a flaw therefore shows up on a photographic plate somewhat darker than its surroundings. The determination is usually made in visual, rather than quantitative, fashion.

X-rays have various advantages over gamma rays. Notable among them is the shorter required period of exposure (a few minutes vs. 15–24 hr) and the better contrast which can be obtained with X-rays. Against this, X-rays call for the use of fairly costly equipment. Furthermore, only one test piece can be exposed at a time since the rays are unidirectional while a gamma-ray source radiates in all directions. Finally, too many places in power plant work are inaccessible to the cumbersome equipment which is needed for X-ray generation.

On the other hand, a gamma-radiator is a very small source (properly shielded to protect the operator). It can be used in numerous locations where X-ray equipment cannot be mounted. The equipment itself is relatively inexpensive consisting, according to Hanstock, merely of "a number of film holders, means for fixing the specimens in the desired positions, and a stand for holding the container of the radioactive sources."

The practice for visual, qualitative inspection of welds by X-rays is standard in power plant practice (it is incorporated, e.g., into ASME construction codes). More recently, attempts have been made to develop quantitative correlation between the radiographic and the mechanical properties (notably strength characteristics) of the specimen. A valuable attempt in this direction has been reported by Masi (4).

Masi calls for three test conditions which must be fulfilled to meet his method's requirements:

1. The intensity of the X-ray beam should be uniform, or of known intensity distribution over the entire field.
2. The defect should be of uniform physical character; for example, the presence of slag filling the void will introduce an error.
3. The maximum cross-section of the defect should be parallel or perpendicular to the X-ray beam.

For these conditions, Masi has developed correlation curves which permit a fairly reliable estimate of tensile strength in terms of the radiograph. Such a quantitative correlation may eventually reduce the number of rejects which are made necessary under present methods if the radiographed welds show evidence of defect.

The high cost of radium and short life of radon have been responsible for the limited amount of interest which these two gamma ray emitters have attracted for non-destructive testing methods. New horizons are opened by two gamma ray sources, which have only recently become available; the isotopes iridium 192 and cobalt 60.

Garret et al. (5) have discussed some of the possibilities and attractions of iridium 192 for radiographic purposes. The gamma rays emitted by this isotope are most intense in the range 305 to 467 ($K\mu$). This is a relatively

low energy level with the result that this source is most suitable for these sections of steel (up to, say, 1.5 to 2 in.). At the same time the low energy level reduces the extent of protective measures which must be taken for the operator's safety.

A suitable shape for the metal is a cylinder of 3 mm diam and 3 mm length. The gain in radiation by going to larger dimensions is insufficient to warrant the greater cost and proved geometry for many applications.

The rays emanating from iridium are attenuated into desired conical shape by passage through a suitably shaped aperture in a lead block. After passage through the specimen, the rays impinge on a photographic plate on a fluorescent screen which may be safely viewed in a mirror.

Garrett determined the sensitivity of iridium gamma rays for various test materials and shapes. By sensitivity is meant the thinnest section which can be seen on a fluorescent screen when irradiated. It is found that flat shapes are more easily detected than circular ones, and spherical forms are most difficult. This last observation is due to the fact that a spherical shape varies in thickness from edge to edge without discontinuities.

For a given shape, the sensitivity decreases with increasing thickness along a curve which reaches a nearly assymptotic minimum.

Iridium 192 as a source of gamma rays has the advantage of higher radiation output than either radium or cobalt 20. Garrett points out further that the lower average energy of iridium's radiations provides better contrast in the radiograph, better sensitivities up to a steel thickness of 2 to 3 in., and results in a less formidable shielding problem.

The main disadvantage in its use is its relatively short half-life which necessitates fairly frequent change of the radiation source.

Garrett has also conducted some tests in the iridium radiography of concrete and finds that embedded steel shapes may be seen at concrete thicknesses up to 10 in.

The technique lends itself also to stereoradiographic investigations. Such an approach, made possible by the relatively high speed of iridium radiography, permits accurate location of voids and flaws in the interior of welds and metals.

A valuable paper by Schwinn (6) has explored practical applicability of radiography by cobalt 60 in steel welds. This radiation source is valuable for the same reasons of portability and small source size which have been outlined above for iridium 192. Similar techniques are employed in the use of either emitter except that cobalt requires more elaborate safety precautions.

Schwinn points out that the high intensity of cobalt 60 gamma radiation makes it an ideal source for objects with high subject contrast. It is a cheaper source than radium even when account is taken of cobalt 60's shorter half-life. Originally, the economics of cobalt 60 compared unfavorably with those of X-ray radiography but the future cost trend is in favor of the cobalt isotope as it becomes more readily available.

For small plate thickness (1-in. steel) sensitivity of cobalt 60 radiographs is somewhat inferior to radium which, in turn, is substantially below the sensitivity obtainable with X-ray. However, exposure time needed for cobalt radiation is significantly less than that called for by radium.

As the thickness of the specimen increases, the sensitivity obtainable with cobalt becomes equal to, and (above 2 in.) even better than, that with radium. Here, the factor of exposure time comes even more pronouncedly in favor of cobalt 60.

These radiation sources are highly suitable up to a steel thickness of about 4 in. Above this point, much detail is lost in the radiograph. The limit is, of course, set by the demand for detail which is set by the particular situation.

C. Ultrasonic Methods

Ultrasonic methods of inspection found their first significant application in 1945. Much knowledge and improvement in technique have since been added, and this field is today in a heyday of development. The two important attractions are the fineness of determination, and the depth of penetration which is possible in ultrasonic inspection.

Typically, ultrasonic waves are generated by applying alternating current across a thickness of quartz plate. This sets up contraction and expansion of the plate, causing propagation of waves into the surrounding medium.

To be able to enter a piece of metal, the ultrasonic wave beam must be applied at near-perpendicularity to the entrance surface since otherwise most or all of these waves are reflected. This is a direct result of the large differential in the velocity of ultrasonic waves in air and in metallic media.

This very property is responsible for reflection from flaws which the beam may encounter in the course of passage through the specimen. Because of the short length of ultrasonic waves, detectable reflection is possible from homogeneities with a linear dimension of as little as 1 mm.

There are several types of ultrasonic inspection equipment available on the market today. Inspection is possible while equipment is in operation and at temperatures up to 200 C.

Ranking in importance among applications of ultrasonic inspection are **corrosion measurements**—either spot tests or periodic complete surveys. These are, in effect, modified measurements of metal thickness at various points of the plant. The cost per reading is only 10 to 20 per cent of that called for by conventional drilling plus visual inspection. This is without consideration of the effect of shutdowns which drilling methods of inspection often necessitate.

Coverage can be made as detailed and as disperse as may be needed and very complete surveys of individual pieces of operating equipment are feasible and common.

Next in importance to corrosion inspection is the **detection of flaws** (fatigue cracks, internal defects) in which ultrasonic testing methods have proved particularly valuable when applied to such items as crankshafts, bolts, crossheads. The value of this type of inspection for proper maintenance and turnaround scheduling, and for the avoidance of many emergency conditions, is quite evident.

Conclusion

Most of these techniques of non-destructive testing, be they radiographic, ultrasonic or whatever, were originally developed for needs other than those of power installa-

tions. Communications between the different industries are often quite limited so that proved tests which have found wide acceptance in one field are quite limited in use by other industries.

Thus it is that some of the non-destructive testing methods here described have a relatively long history in such fields as pump and compressor manufacture, steel fabricating, while their adoption by power plants has lagged. It appears, however, that this situation is changing.

Only the last 6 to 7 years have seen rapidly growing introduction and acceptance of many of these techniques in power stations where they prove their value by measuring important aspects which have, heretofore, been either inaccessible to determination or which have called for tests of much higher unit cost and where conventional inspection calls for plant shutdown, while the new techniques can be carried out without cessation of operations.

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Growth of Pipelines to Transport Solids Foreseen

The pipeline industry's great challenge is in the future and will be in those scientific and economic areas of the world now not fully developed, **Charles C. Whittelsey,** president of Ford, Bacon & Davis, Inc., New York firm of engineers-constructors, predicted in an address before the Southern Research Institute's conference on "Tomorrow's Transportation" at the Dinkler-Tutwiler Hotel, under the chairmanship of **Thomas W. Martin,** board chairman of the Alabama Power Co.

"Instead of buying prime movers designed to last 200,000 to 300,000 hr we will buy one to last 50,000 hr," Mr. Whittelsey said. "When it wears out we will throw it away and buy a new one, saving money in the process." Citing the example of a compressor station, he said: "Let's suppose that we could reduce the cost of a compressor station by 30 per cent by using less rugged equipment. Considering the current costs of borrowing money and attracting risk capital, the savings in interest alone over a period of 11 years would be equal to half of the original compressor station cost." "This," he added, "would permit replacing all the major equipment and still saving the customers the extra depreciation and taxes that a larger, more permanent installation would require."

"Some pipelines of the future," Mr. Whittelsey continued, "will carry several products at the same time, to be separated at their destination, while others will act as great mixing vats, allowing the chemical processing to take place during transit."

Any inert solid material, the speaker maintained, can be transported through a pipeline, and in most cases at lower cost than by any other form of transportation. Widespread use of solids within pipelines waits, he said, on a large and dependable demand for the product. Coal is already being carried over 100 miles by pipeline.

Instrument Society Honors Award Winners

Honors and awards were conferred today by the Instrument Society of America upon sixteen members of the instrument profession, for their "contributions and achievements to the art and science of instrumentation." The awards were made at a luncheon held by the Society during its 15th annual meeting held in conjunction with ISA's Fall Instrument-Automation Conference & Exhibit in New York Coliseum. In addition, lifetime Honorary Membership is to be conferred on **Dr. Allen V. Astin,** director of the National Bureau of Standards. He will be the eighth man to be so honored by the Society since it was founded in 1946. Several of the awards were bestowed for the first time this year.

The Distinguished Achievement Award of the Society conferred for the first time this year, consisting of $500, a plaque and certificate, went to **Dr. Erwin Müller,** Research Professor of Physics, Pennsylvania State University, for "Brilliant achievements in the field of ion emission microscopy and particularly for his invention and application of the ion emission microscope in the physical chemistry of surfaces."

The Excellence of Documentation Award for 1960, also conferred for the first time this year by the Society, went to **Arthur Freillich,** of Ardmore, Pa. Mr. Freillich, a research engineer with the Burroughs Corporation Research Center, Paoli, Pa., was cited for "the clarity and simplicity of his explanation of process computer control concepts, and his statement of the complex subject of process computer applications without bias and in meaningful terms." The award, consisting of $500, a plaque and certificate, was for articles published in the July, 1959, issue of the ISA JOURNAL, official publication of the Society. The articles were based on a paper presented by Mr. Freilich at the 2nd National ISA Chemical and Petroleum Instrumentation Symposium, held in St. Louis, in April, 1959.

The Arnold O. Beckman Award of $1000 went to **B. M. Horton,** chief of the Systems Research Laboratory, Diamond Ordnance Fuze Laboratory, Ordnance Corps, Department of the Army, for "Outstanding technical contributions in the field of fluid amplifiers."

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

By IGOR J. KARASSIK*

Worthington Corp.

Steam Power Plant Clinic—Part XX

QUESTION

Before returning 2300-volt motors to service following extensive electrical repairs on the distribution system, it is desirable to check rotation of equipment. We are interested to know if it is necessary to uncouple the drive from the pump before "bumping" in the case for (1) a vertical shaft propeller "mix flo" pump having a capacity of 82,500 gpm and (2) a 1600 psi, 700,000 lbs per hr boiler feed pump having six stages and barrel casing construction.

ANSWER

Very emphatically, the answer is that the motors should be uncoupled from the pump before trying out the motor rotation, both in the case of the vertical pump and in that of the barrel type boiler feed pump.

Your question speaks of a propeller "mix-flo" pump and these two terms are somewhat contradictory. A propeller pump is an almost true axial-flow pump (as shown on Fig. 1) while a mix-flo pump is a lower specific speed type with both a radial and an axial flow component in the impeller (as in Fig. 2). Either type, however, can be damaged if the motor is started in a reverse rotation. These pumps, as well as the boiler feed pump (Fig. 3) have a number of shaft nuts which are generally threaded so that they tend to tighten under normal rotation. For instance, the vertical propeller circulating pump shown on Fig. 1 has an impeller nut, a shaft sleeve nut and a coupling nut. The mix-flo pump on Fig. 2 shows an impeller nut. The boiler feed pump on Fig. 3 has a coupling nut, two shaft sleeve nuts, a balancing device nut and a thrust collar nut, all threaded to tighten from normal rotation.

Of course, it is the general practice to use set-screws or some equivalent to lock these nuts in position. Nevertheless, it must be remembered that a motor will accelerate very rapidly—in either direction. The danger exists of one of these set-screws shearing and the resulting damage can be quite extensive.

This is a question which on occasion also arises in connection with small vertical turbine type pumps which use screw-type couplings to connect individual lengths of shafting. The hand of thread used in these couplings is also such that during normal pump operation the torque exerted by the motor acts to tighten the threads.

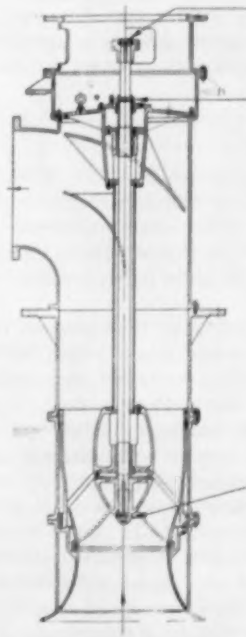


Fig. 1—Vertical propeller circulating pump rates as almost a true axial-flow design and can suffer from a reverse rotation

* Consulting Engineer and Manager of Planning, Harrison Div.

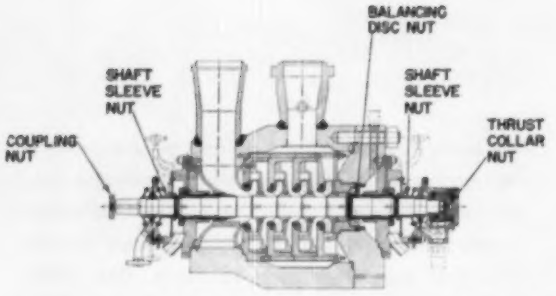
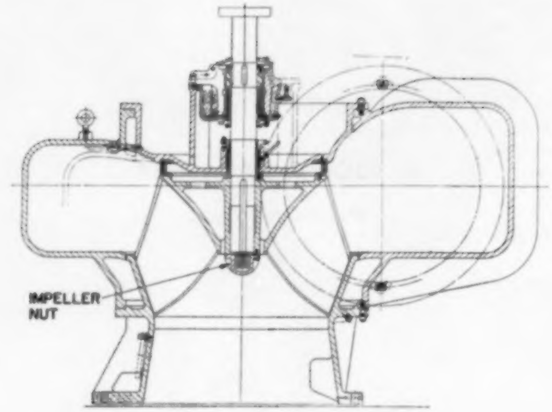


Fig. 3—Boiler feed pump such as above employs a number of nuts as shown above and under a reverse flow condition the set screws backing these nuts in position can shear

Fig. 2—Both radial and axial flow components are present in a "mix-flo" pump and hence it is wise to uncouple pump from drive in testing for direction of rotation →



If the motor stops and reverse flow takes place through the pump, the latter acts as a turbine and runs in reverse rotation, producing torque to drive itself and the motor. Under this condition, the torque developed by the pump acts on the coupling thread exactly as when the motor was driving the pump. Therefore, the coupling threads will not unscrew.

On the other hand, if the motor of this pump is wired incorrectly, the pump will start in the wrong direction and the motor torque will act to unscrew the coupling. For this reason, motor-disengaging clutches or non-reversing ratchets are used in some of the hollow-shaft motors used to drive vertical turbine pumps. Regardless of this, it is imperative in my opinion to try out the motor rotation with the pump uncoupled. Frankly speaking, I see no particular difficulty in following this procedure, especially since the pump and driver will be uncoupled during the realignment which is necessary whenever a motor has been removed for servicing. If the motors have not been moved and only the distribution system has undergone electrical repairs, there is some possibility that the leads will have become reversed. The pumps should be uncoupled, and rotation checked. Advantage can be taken of this uncoupling to check pump and driver alignment.

Question

In several of your articles discussing variable speed operation of boiler feed pumps, you have mentioned that pumps should not be operated below a certain minimum speed. Could you explain the reasons for this arrangement?

Answer

Actually, my recommendations on minimum speed have always referred to the initial start-up of a new steam power plant rather than to normal operation. But in general I might say that whether a minimum speed should or should not be set is partly a matter of opinion and partly of design.

If a pump is designed so as to depend on the support given by internal running joints which act as water-lubricated bearings, then certainly there must always be provided a water film at these joints to act as a lubricant for the internal bearings. Therefore, some minimum pressure would have to be maintained across these internal joints—a pressure which can only be available if each stage of the pump generates some 50 to 100 psi pressure. This requirement, in turn, would dictate that the pump should not be operated below a certain minimum speed, that is a speed sufficient to generate this pressure. This minimum speed would then apply throughout the entire lifetime of the pump.

On the other hand, if the pump design is such that no dependence is made on internal water-lubricated bearings for supporting the rotor, there is no basic mechanical requirement for any minimum operating speed. For instance, many boiler feed pumps arranged for steam turbine drive are capable of operation at speeds as low as 30 rpm on turning gear, once the pumps have been adequately warmed-up and reasonably uniform temperatures exist throughout the pump casing barrel.

A different problem exists during the initial operation of a steam power plant. Regardless how carefully the piping and related equipment has been cleaned prior to the start-up, there is always the possibility that small particles of foreign material (such as mill scale or brittle oxides) will find their way into the boiler feedwater circuit. If any such particles get into the wearing ring or balancing device clearances, there is imminent danger of damage to the pump. There is very little torque available to the pump at extremely low speeds, while the torque required to overcome the dragging friction caused by particles lodged in the close clearances increases. As a result, the moment that the available torque is exceeded by the required torque, the pump will seize. In the case of boiler feed pumps which are built of stainless steel material (and these have easily galling characteristics), the seizure is accompanied by severe damage to the metal surfaces and, potentially, by the destruction of the pump internals.

It is to avoid this possibility that I have been recommending to run boiler feed pumps at a speed high enough to develop something like 100 psi per stage during the initial operation of the steam power plant. I believe

that this pressure differential will cause sufficient flow to take place through the close clearances and to wash out any particles that would have a tendency to lodge in the clearances. The time element during which this minimum speed should be maintained, is of course, problematic and must be left to the operator's judgment of the relative cleanliness of the feedwater piping. Once danger of particles entering the pump clearances becomes insignificant, all minimum speed restrictions can be removed.

Incidentally, should a pump ever suffer a seizure that may have been caused by the presence of foreign matter within the clearances, it is recommended that steps be taken to clear the obstruction before time and effort is expended at stripping the pump down. It may well be that the interference is not a major one and that it can be easily corrected. The pump should be uncoupled from its driver and the bearing bushings removed. If the pump is provided with conventional stuffing boxes, the packing should also be removed. Then the rotor should be moved gently both axially and up and down. If it is possible to back-wash the pump at this time, the chances of removing the obstruction from the foreign matter are excellent.

Effective Teaching for Young Engineers

One of the paradoxes of American education is the widespread cricism for too much methodology on the secondary school level, while many educators show increasing concern for the almost total lack of improved methodology for teaching on the college level. Many teachers of undergraduate subjects have had no formal instruction in the principles of learning, in developing lesson and course plans and objectives, and in evaluation of their own instruction. In fact, there is a widespread belief that concern for the methods of education is not consonant with creative teacing at the college level.

To consider this and related questions in college teaching, the College of Engineering and Architecture of The Pennsylvania State University held an institute on effective teaching for young engineering teachers from August 29 to September 9 on the University Park campus. It was given under the auspieces of the American Society for Engineering Education and the Engineers Council on Professional Development. It was supported by a grant from the Ford Foundation.

Attending the institute were 25 young engineering teachers with one to three years' experience (known as YETS) and ten mature engineering teachers (METS) with ten or more years of teaching experience.

Purposes of the institute were (1) to provide training in the fundamental principles and use of effective teaching methods (2) to orient young teachers to their professions as educators and (3) to encourage research in methods to improve learning. It is hoped that the YETS and METS will serve as a seeding force to broaden discussion on these purposes in their own institutions. The METS plan to institute training programs as well.

The entire two weeks of intensive study supported the view that mastery of his subject is still the most important attribute of a good college teacher. There was equally strong evidence that knowledge of the principles of learning could add immeasurably to the creative powers of the teacher. Applied widely in the engineering colleges, the application of learning principles could significantly upgrade the quality of students now turned out. (On this point, there was general agreement that today's engineering students were the best the colleges had ever trained, but that increasing complexity of knowledge demanded additional improvement.)

It was pointed out that engineering teachers had a dual role. They are first engineers who must set a high professional standard for students at a pliable age. Equally important, they are professional teachers who, if they perform this role properly, lead the student into a useful life.

Eric A. Walker, President of Penn State and of the American Society for Engineering Education, opened the Institute with a challenge to improve the quality of engineering teaching. He noted that many professors had had no more training in teaching than "having listened to both good teaching and bad."

"When many of our teachers have never even seen a learning curve or a forgetting curve, I wonder if we are really paying attention to our main business," Dr. Walker commented. He said, however, that ASEE and its members were probably doing as much as any other professional association to improve teaching quality.

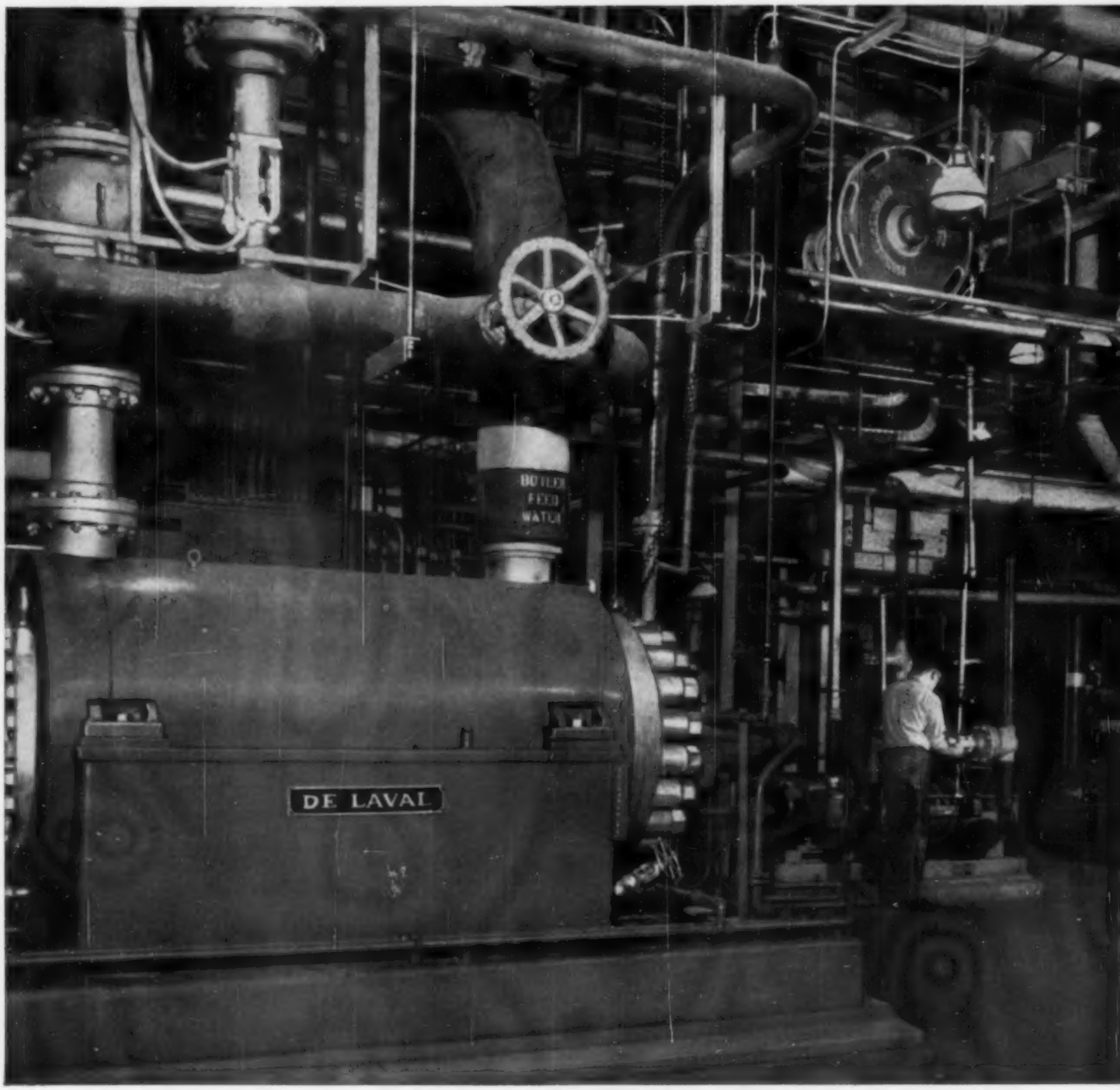
B. R. Teare, Jr., Dean of Engineering, Carnegie Institute of Technology, and past president of the ASEE, described the principal objectives of engineering education as: learning root knowledge and basic principles with real understanding, learning to solve new problems, and learning how to extend knowledge. He added two objectives that are sometimes overlooked—learning to communicate with clarity, precision and interest, and acquiring an understanding of the economic, social, and human aspects of technical work. He quickly noted that the last objective is a difficult one to achieve, and that perhaps no more than three could be achieved in a single course.

W. J. McKeachie, Professor of Psychology, University of Michigan, stressed the value of the discussion method in developing concepts or teaching problem-solving skills because of the advantages of immediate feedback by the learner. He suggested a combination of lectures and discussion as the best system if the goal included the imparting of information and concept development.

Correction Notice:

The article "Boiler Problems Associated with Use of Bunker C Fuel," April issue, pp. 42–47, carried a table on p. 46 listing the "melting points of possible deposit compounds." The figure for sodium pyrosulfate ($Na_2S_2O_7$) was incorrectly listed. We received correction notices from many widely separated readers. We quote one, "My information" (quoting from Physical Constants of Inorganic Compounds, "Handbook of Chemistry and Physics")" is that this melting point should be 756 F decomposing at 860 F with evolution of SO_3." Thank you reader W. F. Crowther, divisional chemist, Central Electricity Generating Board, Portsmouth, England.

DE LAVAL Boiler Feed Pumps part of modernization



Each De Laval pump has intermediate pressure bleed off for use in controlling steam temperature from reheater.

A RUSSIAN VIEW . . .

Radiant Heat Exchange in a Boiler Furnace Fired with Natural Gas*

**By F. L. KAZAKEVITCH† A. M. KRAPIVIN†
G. I. ANOFRIEV† I. G. VESELY††**

THE heat exchange process in steam boiler furnaces is for the most part achieved by radiation. This process is a very complex one. Theoretical considerations based on observing phenomena taking place in the boiler furnace allow us to obtain an approximate equation of the relationship between the basic parameters of the absorption process. The formulas calculated by the Central Scientific Research Institute for Boilers and Turbines shown in Reference 1 are based on experimental data with the aid of the theory of similarity. The method of the Central Scientific Research Institute for Boilers and Turbines, being empirical, gives satisfactory results if it is used strictly within the bounds of the experimental material on which it is based (Reference 2). There is an opinion (Reference 3) that in calculating the heat exchange in the furnace chamber while using natural gas as the fuel the norm method does not give sufficiently reliable results and a substantial correction is needed. With this in mind the authors, in addition to the balance tests of small capacity boilers firing natural gas, conducted a study of radiant heat exchange in the furnace of one of these boilers. A sectional elevation of the boiler with the indicated location of the measuring instruments is shown in Fig. 1. The boiler had previously

Editor's Note: One of the authors of Reference 4, A. R. Mumford, offered these comments on this Russian approach.

"We note that combustion air temperature (15 C) was low compared to the Sterlington tests discussed in Reference 4 which were run at 500–600 F.

"The Russian comment that flue gases are better mixed after passage through a tube bank we find highly questionable.

"There appears to be no consideration given to furnace heat absorption by convection and we know of course that this can be a significant factor.

"The determined furnace efficiency (32–39 per cent) appears too low. The tests of Ref. 4 indicated efficiencies up to a maximum of about 48 per cent. This gap is probably accounted for by failure of the Russians to consider convective absorption as a factor in furnace effectiveness."

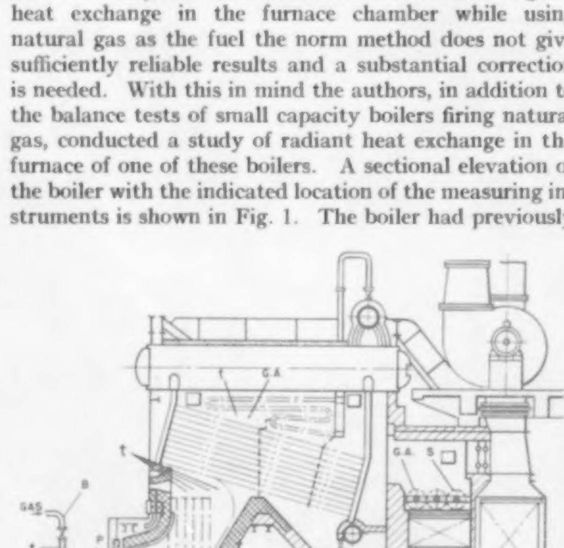


Fig. 1.—Longitudinal view of test boiler showing: B, place where gas consumption is measured; t, temperature taps; p, pressure taps; s, draft taps; GA, gas separation for analysis

* Translated from the Russian publication *Teploenergetika* by V. A. Ferencko and A. Fedorowsky, Combustion Engineering Inc.
† Candidates of Technical Sciences.
†† Engineer of the Dnieprepetrovsk Institute of Railroad Transportation Engineers.

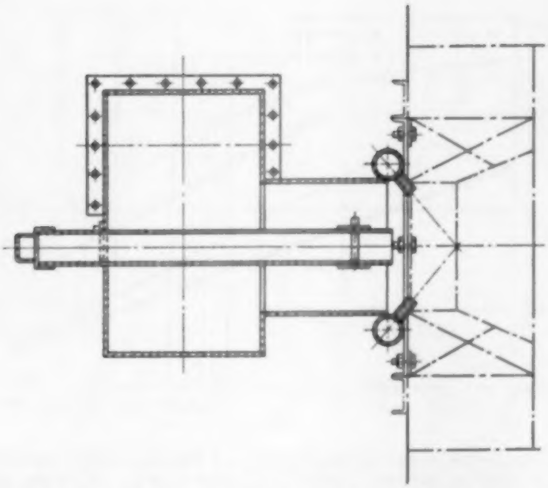


Fig. 2—Ring type gas burners of the above design were installed in Fig. 1

operated on solid fuel. (See stoker in place, Fig. 1)

Design and calculated characteristics of the tested steam generator were as follows:

Output: D = 14 tons/hr | Furnace volume: V_t = 26 m³

Furnace radiation absorption surface: H_r = 20.5 m² | Furnace wall total surface: F_w = 62.3 m²:

Furnace waterwall effectiveness factor: φ = 0.33.

In connection with the boiler conversion to natural gas firing, two ring type gas burners, Fig. 2, were installed on the front furnace wall with a rated output of 650 m³/hr with forced air injection. As shown in Fig. 2 the burners consist of circular tubes from which the gas discharges in the form of fine jets from the nozzle at an angle of about 50 deg. toward the air current. The average air temperature during tests was 15 C. The furnace floor was constructed of firebrick laid on cross beams which were placed in position over the grate.

Measures were taken during the test to insure a stable rate of operation for the steam generator. This is illustrated in Fig. 3 where time and corresponding quantity changes are shown.

Gas consumption was controlled by means of a throttling orifice installed on the common boiler gas header supplying both burners. Leaving velocities of gas and air at rated capacity were 35 and 17 m/sec respectively. Micromanometers plus indicating and recording gas meters were connected in parallel. The gas throttle orifice, installed in front of the gas-distributing point of the boiler, duplicated the gas consumption measurement. Practical results were obtained from the two indicated meter measurements for the deviation amounted to only a few tenths of a per cent.

The boiler burned natural gas from the Shebelinsky field. The heating value of the gas Q_h^p was obtained by calorimetric data taken twice every 24 hr at the laboratory of the State Regional Electric Power Plant. The average gas composition was taken from data furnished by the All-Union Scientific Research Institute of the Gas Industry which equaled:

CH_4 = 93.1%	C_2H_6 = 3.3%	C_3H_8 = 0.8%
C_4H_{10} = 0.7%		C_5H_{12} = 0.6%
CO_2 = 0.1%		N_2 = 1.4%

The corresponding heating value of the gas, Q_h^p was 9050 kg cal/m³.

The excess air coefficient was determined by flue gas analysis. Samples were taken after the first gas pass and the coefficient was assumed to be equal to the coefficient in the furnace.

Mixing of flue gases during their passage between boiler tubes secures more reliable mean values of percentage content of the individual flue gas components. The gas analysis was done by manually operated type GKLP (main administration for the chemical industry) gas analyzers. In addition complete flue gas analysis

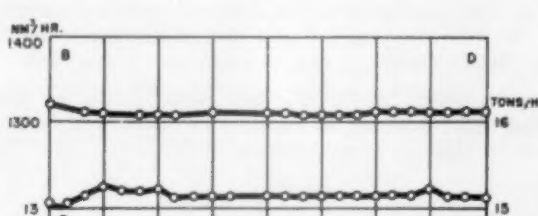


Fig. 3—Changes during test period are shown for: B, Gas consumption; D, boiler rating; p, drum pressure; t_{he}, superheated steam temperature; t_{yx}, exit gas temperature and ΔS_B, economizer resistance

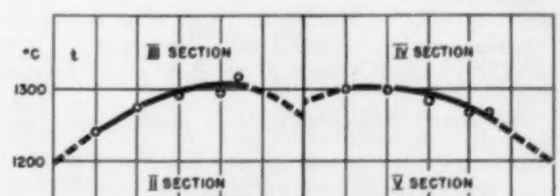


Fig. 4—Gas temperatures at furnace exit (at various distances from the front wall)

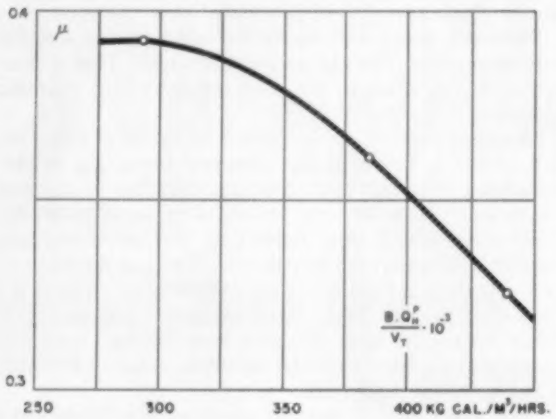


Fig. 5.—The relationship between the direct efficiency of the furnace and the apparent furnace liberation for $a_t = 1.12$

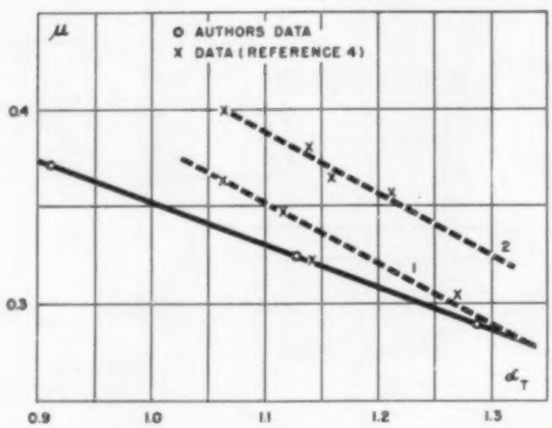


Fig. 6—The relationship between the direct efficiency of the furnace and the excess air coefficient $[(B \cdot Q_h^p)/V_t] = (440 \times 10^3)$. 1—100 per cent load; 2—75 per cent load

was made with the aid of a type VTI (Heat Engineering Institute) gas analyzer. Flue gas samples were taken in "Koro" aspirators.

The basic value which was formulated in the test appears as the direct efficiency of the furnace:

$$\mu = \frac{Q_r}{\eta_t \times Q_h^p} \qquad (1)$$

where:

Q_r = quantity of heat transferred by radiation to the furnace heating surfaces

η_t = furnace efficiency

In the adopted method of the test the direct furnace efficiency was determined as the difference between the heat input and absorption in the furnace:

$$\mu\eta_t Q_h^p = Q_h^p + Q_b - 0.01\ \Sigma qTQ_h^p - \Sigma VG\ \vartheta_t'' \qquad (2)$$

where:

Q_b = heat transmitted into the furnace by air, kg cal/nm³

$\Sigma qT = q_3 + q_b'$ = furnace heat loss from incomplete chemical combustion and in the environment

$\Sigma VC\ \vartheta_t''$ = heat content of the gases at the furnace exit

The greatest difficulties arose in measuring the gas temperatures at the furnace exit ϑ_t''. As a rule the temperature field in this cross section is characterized by great unevenness which required that the temperature be measured at various points in the cross section. In order to determine the mean weighted value ϑ_t'' it was necessary moreover to know also the field of velocity in the exit cross section. However, attempts to measure the gas velocity with type VTI pitot tube for hot gases proved unsuccessful. The dynamic pressure appeared too small so that it excluded the possibility of obtaining reliable readings. ϑ_t'''s were determined by measuring with a planimeter the empirical curves of temperature distribution along the boiler tubes. The temperature curves were obtained from six cross-sections along the furnace width. The temperature was measured by platinum rhodium-platinum thermocouples in a water cooled lance; the exhaust gas being aspirated by means of a steam ejector. The thermocouple junction was placed in a shield made in the form of a triangular screen. The device was inserted into the furnace through openings in the front furnace wall and was adjusted externally for different depths.

(Editor's Note: A. R. Mumford quoted earlier in this article feels the method of shielding the couple was inadequate for this type of measurement.)

TABLE I Condition	Designation	Test No. 1	2	3	4	5	6	7
Boiler Load, tons/hr	D	16.06	16.05	13.8	13.98	13.85	13.81	11.09
Boiler steam pressure, absolute atmospheres	p	13.9	14.0	13.3	13.3	13.6	14.0	13.0
Gas consumption, m³/hr	B	1280	1260	1088	1110	1260	1151	850
Gas heating value, kg cal/m³	Q_H^p	9030	9066	9066	9049	9048	9050	9049
Furnace heat liberation kg cal/m³ hours	$\frac{B \cdot Q_H^p}{V_t} 10^{-3}$	445	440	380	386	439	401	296
Excess air coefficient in the furnace	α_t	1.29	1.13	1.2	1.11	0.91	1.61	1.14
Theoretical combustion temperature, °C	ϑ_a	1710	1905	1825	1950	2000	1450	1900
Temperature of gases in furnace, °C	...	1237	...	...	...	...	...	...
Measured, °C	ϑ_t''	1255	1323	1237	1292	1267	1135	1217
Calculated according to the norm method (Reference 1), °C	ϑ_{tp}''	1294	1370	1290	1324	1343	1155	1240
(Direct) Furnace Efficiency	μ	0.29	0.325	0.33	0.36	0.37	0.23	0.385
Dimensionless temperature of gases at the furnace exit	θ_t''	0.76	0.74	0.72	0.70	0.68	0.82	0.69
Boltzman criterion	B_0	0.98	0.645	0.63	0.51	0.46	1.53	0.43
Degree of furnace blackness	a_t	0.41	0.39	0.41	0.41	0.4	0.43	0.42
Parameter	Bo/a_t	2.4	1.65	1.54	1.24	1.15	3.56	1.02
Feedwater temperature, °C	t_B	74.7	73.1	74.8	74.9	74.7	74.3	73.6
Superheated steam temperature, °C	t_{he}	310	295	297	287	295	318	274
Exit temperature, °C	t_{yx}	152	142	140	125	133	166	112
Heat loss to exit gas, per cent	q_2	7.2	6.2	7.2	4.8	5.5	11.1	4.6
Heat loss from incomplete combustion, per cent	q_3	0	0	0	0	13.0	0	0

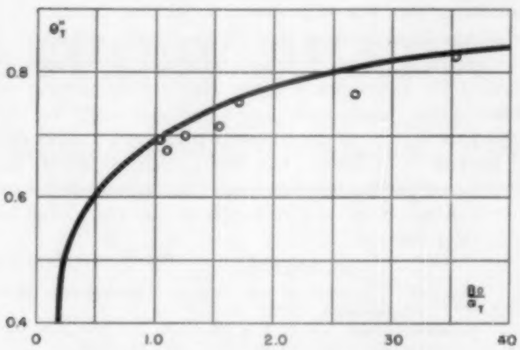


Fig. 7—The relationship of the dimensionless temperatures at the furnace exit and the Bo/a_t parameter

Fig. 4 shows examples of temperature curves obtained in the test with the excess air coefficient α_t = 1.11 and the apparent furnace heat liberation equaling 386.10^3 kg cal/m^3 hr. Note the high temperature values at points located in the immediate vicinity of the furnace rear wall. This is due to the fact that the waterwall effectiveness is very slight (φ = 0.33). It appears that in the center of the flame the temperature reaches 1600 C – 1650 C which causes the furnace refractory to melt.

Visual observation of furnace conditions showed that with normal excess air coefficients the flame is short and clear. In tests with a low excess air coefficient it was observed that the flame acquired a violet tint.

Radiant heat exchange calculation results in the boiler furnace are shown in the table (I). As can be seen from the table the excess air coefficient varied within wide limits from 0.91 to 1.61. The second parametric quantity—the apparent furnace heat liberation varied from 296×10^3 to 445×10^3 kg cal/m^3 hr.

The temperature traverse of the furnace exit cross section was taken twice in test No. 1 in order to check the stability of the furnace operating conditions. The average gas temperatures at the furnace exit proved to be sufficiently close (1237 C and 1255 C).

The table (I) also lists data characterizing operation of the steam generator under various conditions.

The table data were used for plotting graphs representing the relation:

$$\mu = f\,\frac{B \cdot Q_h^p}{V_t} \tag{3}$$

when α_t = 1.12
and

$$\mu = f(\alpha_t) \tag{4}$$

when $\dfrac{B \cdot Q_h^p}{V_t} \approx 440 \times 10^3$ kg cal/m^3 hr

For the value α_t = 1.15 which is normal for a gas-fired furnace; the direct efficiency as can be seen from the table amounted to 32–39 per cent which is comparatively small. The results of a detailed examination of radiant heat exchange in a gas-fired furnace of a steam boiler having a capacity of ~170 tons/hr (Reference 4) is shown by broken lines in Fig. 6. The furnace of the boiler was completely water cooled. The gas temperatures at the furnace exit under 100 per cent load in these tests turned out to be:

At a minimum value
α_t = 1.065, ϑ_t'' = 1338 C;

At a maximum value
α_t = 1.27, ϑ_t'' = 1300 C

The given data shows that μ in furnaces of high capacity boilers is also not large. In this connection it is impossible to agree with the statement in Reference 5, that the direct furnace efficiency of a type PK-19 boiler firing natural gas goes up to 62 per cent under normal load. The indicated authors evaluated the gas temperatures at the furnace exit in an indirect manner that evidently involves serious errors.

Of interest is the comparison of the experimental data and calculated data in Reference 1 of heat exchange in the furnace of the tested boiler. As a basis of calculation in Reference 1 an equation was used linking together the dimensionless* temperature of gases at the furnace exit, $\vartheta = T_t''/T_a$ with the dimensionless group B_0/a_t:

$$\vartheta_t'' = \frac{(B_0/a_t)^{0.6}}{A + (B_0/a_t)^{0.6}},$$

$$\mathrm{Bo} = \frac{\varphi B_p\, VC_{cp}}{4.9 \times 10^{-8} - \zeta H_r T_a^3} \tag{5}$$

where:

B_0	=	Boltzmann criterion
a_t	=	furnace emissivity
T_t'' and T_a	=	absolute values of the gas temperatures at the furnace exit and the theoretical combustion temperature
B	=	gas consumption
VC_{cp}	=	average gross thermal capacity of the combustion products 1 mm^3 of gas
H_r	=	furnace radiation absorption surface
ζ	=	conventional fouling coefficient of the heat absorbing surfaces taken for gas fuels = 1
φ	=	coefficient of heat retention
4.9×10^{-8}	=	radiation coefficient of an absolutely black body

The coefficient A in our case is assumed to equal 0.445.

The found values ϑ_t'', B_0 and a_t are listed in the table. The equation (1) is used for plotting a graph for $\vartheta_t'' = f(B_0/a_t)$. This graph is presented in Fig. 7 where it can be seen that the empirical points are located sufficiently close in relation to the curve which is constructed

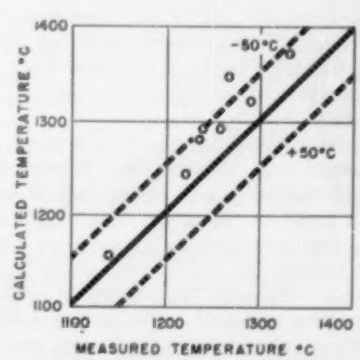


Fig. 8—Comparison of the calculated and the measured gas temperature values at the furnace exit

by equation (5).

Fig. 8 shows the comparison of the $\vartheta_t R''$ and the measured ϑ_t'' values of the gas temperatures at the furnace exit. The temperature $\vartheta_{t''}''$ was calculated as shown in Reference 1.

The temperatures measured under various furnace operational loads proved to be lower than the calculated temperatures in the overwhelming majority of tests by approximately 40 C. It is noted that the treatment of the experimental heat exchange data in the boiler furnaces on which the norm method (Reference 6) is based showed that for gas and solid fuels more than 80 per cent of tests produced a divergence of ± 60 C between the calculated and empirical temperature values.

Conclusions

A radiant heat exchange test in a boiler furnace and a comparison of the empirical values and values found by calculating the gas temperatures at the furnace exit (Reference 1) permits us to state that for small capacity boiler furnaces operating on natural gas the calculation obtained by Reference 1 gives thoroughly satisfactory results.

The fact that in all the tests the measured temperature V_t'' proved to be lower than the calculated shows that the emission properties of natural gas flame have characteristics which were not reflected in the calculated formulas (Reference 1).

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Future Energy Needs Discussed at Widely Separated Points

From Schenectady, New York, came reports that a world famous GE turbine designer said that future sources of power may be found in harnessing the stream produced by underground explosion of hydrogen bombs. Such a plan for power has been considered as a part of "Operation Plowshare," a program for peaceful use of atomic bombs. The plan was among ideas discussed by **Dr. Edward Teller,** "father of the hydrogen bomb," at an American Society of Mechanical Engineers' Technical Development Committee Meeting in New York earlier this month.

"Energy from such bombs seems to be low in cost," **Glenn B. Warren,** vice president of General Electric Co. and consulting engineer for the turbine division, stated. Mr. Warren reported Dr. Teller said other peaceful uses of nuclear bomb explosions underground could include:

Creating underground reservoirs for flood waters and replenishing subsoil water from flood waters, which now run off.

Open-pit strip-mining to depths of 500–700 ft, possibly for oil shales or oil sands.

Moving earth to make artificial harbors.

Distillation of oil shales in place underground.

Underground chemical factories which would change the characteristics of minerals and other materials.

Mr. Warren's remarks were made at Watertown, New York, where he received the New York State Society of Professional Engineers' "Engineer of the Year" award for 1960.

Peaceful use of the atom bomb as a power source in the future might work this way, Mr. Warren said:

"We would make a hole in the ground, 10,000 ft or so deep with a large cavern at the bottom, fill it up with water, then drop a bomb into it, say every two or three weeks, and harness the steam that results from heat of the explosion" He said "harnessing of power by this explosion method of fusion might be quicker and easier than with the continuous fusion processes, which are now being investigated and which might require containment of fantastically high pressures and temperatures."

Also, Mr. Warren said, Dr. Teller believes biologists have exaggerated—perhaps by 10 to 1—the possible detrimental fallout effects of nuclear explosions. Mr. Warren added, "nuclear explosions underground would be very completely contained." One of the biggest obstacles now facing "Operation Plowshare," which takes its name from a Biblical reference, is the molding of favorable public and political opinion and understanding toward it, Mr. Warren said.

Later at Bethlehem, Pa., **Capt. C. Harless Parmelee,** USN, told more than 600 delegates attending the National Security Seminar at Lehigh University that failure to meet the rising world demand for energy would spell the doom of the nation's economy and Western civilization.

"Because of the abundance of coal, oil and gas in the United States, nuclear power will be justified economically in other countries before it is ours," Capt. Parmelee believed, but "nevertheless, our demand for electric power is expanding so rapidly that a forecast of our electric generating capabilities in 1980 shows that 100 million kilowatts of nuclear power will be used to make up 19 per cent of the total. This nuclear contribution would just about equal the total generating capacity on the line in 1955."

In his review, he said "our nation is still the leading petroleum producer with our annual production of crude oil accounting for 37 per cent of the world's total." He added that we have only 13 per cent of the world's known crude oil reserves as compared to over 64 per cent located in the Middle East.

"Demand for petroleum products in the United States exceeds that of the rest of the world. While our demand dropped slightly last year, it is expected to grow at an average rate of five per cent a year for the next decade. In oil-hungry Western Europe," he continued, "demand for oil is increasing about four times faster than in the U.S."

Parmelee paid tribute to the nation's electric utility industry as capacity grows at the rate of approximately nine per cent annually. "Even so, electric generating capacity is still struggling to keep ahead of demand in certain areas of the country.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N.Y.C.

Stream Power Plants

By Chas. Donald Swift

$11.50, 491 pages

This book is divided into 20 chapters ranging from initial design concept to plant acceptance tests.

Subjects covered are design and purchase, combustion plant personnel, safety, operation and maintenance, water treatment, cooling towers, condensers, turbo generators, electrical systems. Instruments and automatic control are also covered.

This book was written by a member of a world-wide engineering and consulting service and his work reflects wide personal experiences.

It would be a handy volume for book case of the smaller consulting services in avoiding many of the pitfalls encountered in the preliminary, construction, training, operating and testing periods.

The sequence from plant inception to acceptance is well done. The book is non-technical and is easily read.

Chemical Process Principles—Part II

By Olif. A. Hougen, Kenneth M. Watson and Roland A. Ragutz

$9.75, 567 pages

The fundamental principles of thermodynamics are presented in generalized form, with application to the compression and expansion of fluids, power generation and refrigeration.

The application of these principles are also applied to the calculation of equilibrium composition in both physical and chemical processes.

Engineering Thermo-dynamics

By James B. Jones and George A. Hawkins

$8.50, 724 pages

In addition to the usual basic subjects covered in thermodynamics, the author has included such subjects as "combustion chemical reactions" and chemical equilibrium, vapor and gas power cycles, refrigeration, binary mixtures and heat transfer.

As stated by the authors this text is written as an introduction to the basic principles of engineering thermodynamics and is not confused by application of practical problems. It is well written and is easily understood.

Radiation Pyrometer and the Underlying Principles of Radiant Heat Transfer

By Thomas R. Harrison

$12.00, 234 pages

This text is divided into six chapters ranging from "general principle" to specific cases of "black body" and "non-black body" radiation.

Radiation pyrometers are fully covered and the text ends with a multiple of references, charts and tables.

This text is written for instrument designers but it would also be valuable for classroom work because of the clear and comprehensive explanation of the radiation laws with their mathematical derivations. It would have limited use in applied engineering.

Standard Plant Operator's Questions and Answers—Vol. II

By Steve Elonka and Joseph F. Robinson

$8.00, 255 pages

The subjects covered by this very comprehensive book includes diesels, air conditioning, fuels and firing, compressed air, heat exchangers, gas turbines, cooling towers, building heating lubrication, nuclear power and safety.

A table of U. S. and Canadian engineers license requirements is also included.

This is a well written volume for those about to apply for operating license and would be a good addition to any operating engineer's library.

Internal Combustion Engines — Theory and Practice, Vol. I

By Chas. Fayette Taylor

$16.00, 514 pages

This book can be described as the application of thermodynamics to the internal combustion engine.

Illustrative examples with accompanying graphs are used throughout the book for clarity.

Elementary Theoretical Fluid Mechanics

By Karl Brenkert Jr.

$7.50, 348 pages

In contrast to the usual treatise on this subject the book is developed along the fundamentals with minimun, attention to the practical applicatiom in order to provide a basis for the study of application in the many fields of advanced specialization.

Calculus is used to a great deal; to demonstrate the wide variety of problems that can be solved, when used with the general form of fundamental equation.

The subjects covered: general introduction to fluid mechanics; fluid statics; conservation of matter and energy; momentum and angular momentum; friction; dimensional analysis and model studies; acoustic velocity, cavitation and thermodynamics; boundary layer theory.

This book is highly recommended for its comprehensive coverage of the subjects involved.

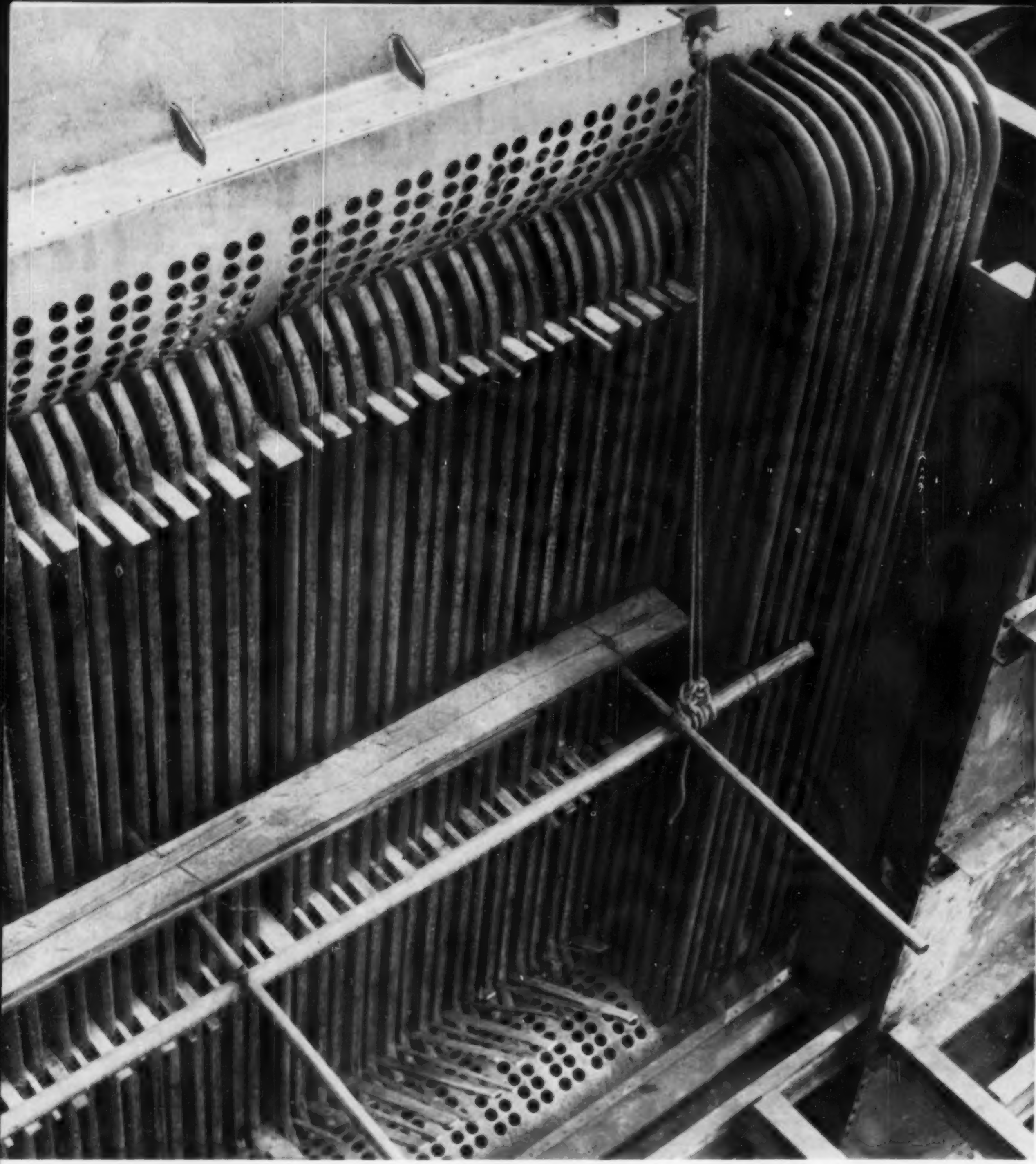
Thermal Engineering

By Harry L. Solberg, Orville C. Cromer and Albert R. Spalding

$9.50, 649 pages

This is a revision and extension of "Elementary Heat Power." The first law of thermodynamics and its application in form of "energy balance" is the unifying theme of the book.

A new addition is the treatment of nuclear energy as a replacement for fossil fuel in power generation.



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18	0.006 IN.	0.003 Square Inches
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14 and 13	12.5% of Wall	0.004 Square Inches
12 and Heavier	12.5% of Wall	0.005 Square Inches

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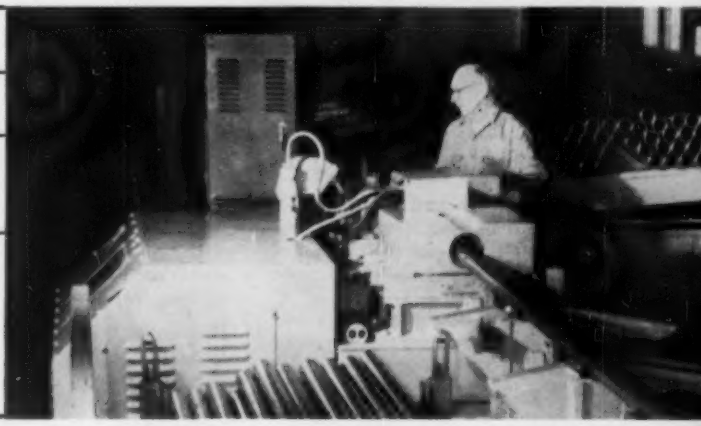

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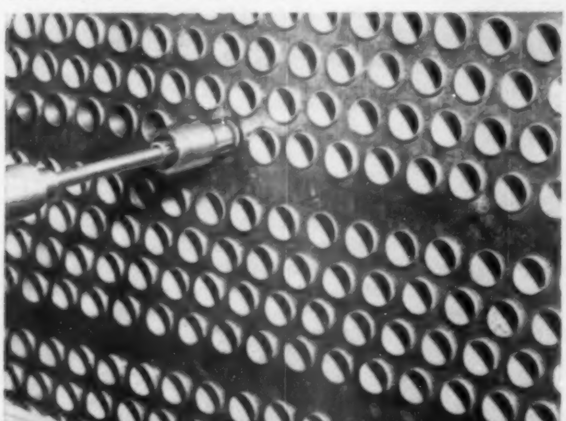

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Abstracts from the Technical Press—Abroad and Domestic

(Drawn from the monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Fuel Technology in Canada. A. Ignatieff. *J. Inst. Fuel* 1960, **33** (May), 223–7.

The following are discussed: (1) Coal industry; (2) oil, natural gas and associated hydrocarbons; (3) research on fossil fuels; (4) uranium industry.

Coalification Progress, Coalification Scales and Classification of Coals Based on Vitrain Analyses. Pt. III. K. Patteisky and M. Teichmüller. *BrennstChemie* 1960, **41** (May), 133–7 (in German).

The various coalification scales have been checked and it is shown that these scales have to be varied with the stage. The limit values (C, O, H contents, V.M., moisture, C.V.) for the 4 large coalification stages are given.

Structure of High-Rank Coals Deduced from Helium Densities. T. S. Polansky, H. J. Donald and C. R. Kinney. *Nature* 1960, **186** (June 4), 792–3.

It is shown that the density gives a closer correlation with hydrogen for high rank coal than specific volume and the equation deduced from a line drawn through the densities of some high-rank coal is: $y = 2.26 - 0.23\ x$, where y is density and x percentage hydrogen. This equation does not hold for bituminous coals for which the equation $y = 0.442 + 0.064\ x$ (y is specific volume or the reciprocal of density) is deduced.

Structure Parameter of Coal Based on Oxidation Experiments. S. K. Chakrabartty, B. K. Mazumdar, S. N. Roy and A. Lahiri. *BrennstChemie* 1960, **41** (May), 138–42 (in German).

The aromaticity in the range of 80–90 per cent C increases from 0.7 to 0.8 and approaches 1 in the anthracite stage. The aromatic hydrogen increases from 30 to 50 per cent of the total hydrogen and reaches 80 per cent and more in anthracite. The average size of the aromatic nucleus does not increase much and possibly consists of 4–5 benzene rings.

Investigations into the Processes in the Coke Oven. H. Echterhoff and M. T. Mackowsky. *Glückauf* 1960, **96** (May 7), 618–26 (in German).

Extended investigations in which samples were taken from various parts of an experimental oven and at various times have shown that the decisive phase in the coke formation is the plastic phase. The rate of heating in the plastic zone determines the mechanical properties of the coke, as well as the amount of fissuring.

Mechanical Handling

Coal Storage and Handling in the National Coal Board. S. Weinberg and D. G. T. Davey. *J. Inst. Fue* 1960, **33** (June), 283–4.

Storage of coal is today almost universally carried out by crawler tractors with a bulldozer blade which enables larger stock piles to be made and compacted and thus reduce the risk of selfignition. The piles are up to 40 ft deep with a density of 80 lb/ft^3 and contain 1-in. vertical tubes for daily temperature measurement.

New Equipment for Stockpiling and Reclaiming. H. R. Keller. *Fördern und Heben* 1960, **10** (May), 319–26 (in German).

A newly developed mobile machine, a cutter-disk loader, is described which is used mainly for reclaiming. It operates either directly or with other mobile intermediate belt conveyors and applications in iron and steel works, gas works and similar plants are illustrated. The economics of such installations are discussed.

Hydraulic Transport of Coal. A. Wright. *Sheffield Univ. Min. Mag.* 1959, 47–70.

The whole subject of hydraulic transportation of coal is covered very fully from the fundamentals of solids flow in a pipeline and the methods of introducing solids into a pipeline, to descriptions of installations abroad and pilot installations in Great Britain. The future of this method of moving coal is discussed and in the appendix three sample schemes are costed in comparison with other methods of transport. (N.C.B. abstract.)

From C.E.G.B. Digest 1960, **12** (June 4), 1433.

Heat: Cycles and Transmission

Heat Transfer. E. R. G. Eckert, J. P. Hartnett, T. F. Irvine and E. M. Sparrow. *Ind. Engng Chem.* 1960, **52** (Apr.), 327–39.

The annual review of the literature of the past year under the headings: (1) Conduction; (2) channel flow; (3) boundary layer flow; (4) flow with separated regions; (5) transfer mechanism; (6) natural convection; (7) convection from rotating surfaces; (8) combined heat and mass transfer; (9) change of phase; (10) radiation; (11) liquid metals; (12) low density heat transfer; (13) measurement techniques; (14) heat transfer applications.

Thermodynamics. G. M. Brown. *Ind. Engng Chem.* 1960, **52** (May), 451–5.

The review of the literature published in 1959.

Pressure Drop in a Duct with Heat Transfer. J. S. Turton. *Engineer* 1960, **209** (May 27), 902–3.

A mathematical analysis.

Steam Generation and Power Production

Fluid Dynamics. C. A. Sleicher, R. A. Stern, L. E. Scriven and A. K. Oppenheim. *Ind. Engng Chem.* 1960, **52** (Apr.), 347–58.

The annual review of literature of 1959.

Temperature Recovery Factors in Steam. H. Barrow and D. J. Ryley. *Engineer* 1960, **209** (May 27), 903–6.

Temperature measurement of the boundary of a fluid in motion is discussed and the results obtained with two different probes are presented.

Steam Generators

Development of a Diagram for the Calculation of Natural Circulation in Water-Tube Boilers and Boiling-Water Reactors. K. Jaroschek and F. Brandt. *B.W.K.* 1960, **12** (May), 189–96 (in German).

The equations for constructing the diagram are developed. The numerical values for a range of parameters obtained by computers are entered in the diagram which facilitates the calculation of the circulation if the tube friction coefficients are known or can be assumed. The diagram can also be applied to boiling water reactors if the resistance of the fuel elements is known.

A New Method for the Rapid Analysis of Results of Thermal Calculations for Steam Generators. S. Kasprzyk. *B.W.K.* 1960, **12** (May), 208–11 (in German).

A single diagram has been constructed for presenting the essential relationships between operational parameters, heat balance and size of heating surfaces. This reduces the time required for calculating the fall in flue gas temperatures as a function of the design of the heating surfaces and facilitates comparison of various projects.

The Behavior of Forced Flow Boilers during Load Changes. M. Ledinegg. *B.W.K.* 1960, **12** (May), 197–206 (in German).

The changes in the heating surfaces occurring in the economizer, evaporating and superheating sections of a Benson boiler during load changes (expressed by a variation of the ratio of fuel : water), the time elapsing from one steady state to the next, and the changes in the temperature level of the tubes have been studied. The difficulties are discussed in assessing the changes at the transition points which wander during the load changes. The times are calculated which elapse until a change of the fuel : water ratio affects the steam temperature, also for the case in which the feed of water is completely stopped.

High Pressure Steam Power Plants. Sulzer Frères S.A.

The tubes of tube-platen reheaters are protected from the direct effect of radiant combustion gases by enveloping them with superheater, evaporating or feed water heating tubes.

Furnaces and Combustion

Bridging the Gap between Fundamental Science and Industrial Combustion. M. W. Thring. *Brit. Pwr Engng* 1960, **1** (June), 88–90.

A brief review of the research carried out into the mixing and reaction processes in furnaces, the development of the turbulent controlled mixing history one-dimensional flame and the results obtained with solid, liquid and gaseous fuels. Possible application on the industrial scale is discussed.

Graphical Method for the Determination of the Combustion Air and Flue Gas Volumes of Solid Fuels. I. Luzsa. *Energie* 1960, **12** (May), 189–2 (in German).

A nomogram has been developed for the rapid calculation of the theoretical combustion air volume and the resulting flue gas volume.

Dimensionless Coefficients of Mixture Formation in Combustion Chambers. Pt. V. W. H. Fritsch. *Energie* 1960, **12** (May), 192–7 (in German).

By means of the dimensionless coefficients developed earlier front, opposed and corner firing are compared. The effect of the central air core in corner firing and the advantages of adjusting the burners to circles of different diameters are discussed. From a consideration of the relative furnace height (H/L), furnace hopper depth (H_1/L) and burner mouth diameter, optimum dimensions for corner-fired furnaces are deduced. Insufficient experimental material has been available to assess the influence of the size and

position of the rear arch in the upper part of a corner-fired furnace. Some ideas of the development of furnace design on the basis of ideal mixture formation are presented. Finally, it is shown that the occurrence of corrosion and slagging and of smoke formation can in many cases be ascribed to faulty mixture formation and improvements can be obtained by modifications resulting in better mixing.

Properties and Prospects of Directly and Indirectly Air-cooled Slagging Furnaces. Contribution to the Realization of a Slagging Furnace without Dry Operation in the Low Load Range. R. Dolezal. *Mitt. V.G.B.* No. 65 1960, (Apr.), 108–17 (in German).

The temperatures in directly air-cooled furnaces would be too high for prolonged operation but such small furnaces might be useful for investigations into ash properties and the evaporation of their constituents at very high temperatures. Indirectly air-cooled furnaces are cooled by media of high boiling point (liquid metals) and their heat transferred in part to the air and in part to steam to be reheated; they can be operated at very low loads with liquid slag removal.

Water-Side Corrosion and Water Treatment

Experiences with Ion Exchangers Operating on the Counter-flow Methods. K. Hofmann. *Mitt. V.G.B.* No. 65 1960, (Apr.), 92–101 (in German).

By using the counterflow principle of regeneration (water flowing upwards, regenerant downward) less regenerant is required. Laboratory, pilot-scale and full-scale plant tests have shown that little more (105 per cent) than the theoretical amount is actually required. The higher cost of these counterflow filters is more than compensated by the smaller number of filters needed to achieve the same degree of demineralization. The results of the tests are given in tables and graphs.

Cold Hardening Surface Layers for Corrosion Protection of Feed Water Treatment Plants. E. A. Ulrich and K. v. d. Heiden. *Tech. Überw.* 1960, **1** (May), 182–6 (in German).

Various kinds of lacquer and varnish were tested with regard to the protective effect for tanks and vessels used in feed water treatment. It is suggested to apply after careful cleaning by sand blasting a basic mass containing zinc dust followed by several layers of epoxy resins containing polyamides. The procedure to be followed is outlined.

Gas-Side Corrosion and Deposits

Corrosion Tests on Materials Exposed in Flue Gases from Oil Firing. M. Haneef. *J. Inst. Fuel* 1960, **33** (June), 285–94.

The relative corrosion rates of carbon steel, cor-ten, stainless steel and normalized or annealed cast iron were determined under controlled conditions. In addition the effects of machining the surfaces and of the angle of impingement of the flue gas were studied. Annealed cast iron showed the highest, cor-ten the lowest corrosion rates.

Problems Associated with Oil Firing of Power Station Boilers. W. S. Robertson and R. Ruddock-West. *Brit. Pwr Engng* 1960, **1** (June), 75–7, 80.

The difficulties experienced when oil firing was introduced in several power stations of the CEGB., are discussed under the headings: (1) Flame impingement; (2) superheat temperatures; (3) superheat fouling and corrosion; (4) low temperature corrosion and fouling; (5) reduction of corrosion; (6) excess air control; (7) smut emission. It is shown that the difficulties could be overcome and corrosion reduced to acceptable levels by using the minimum excess air possible and complete burning of the oil, so that the use of additives could be dispensed with.

Corrosion and Metal Wastage on the Flue Gas Side of Boiler Plant. W. D. Jarvis. *Brit. Pwr Engng* 1960, **1** (June), 81–5.

A summary of experience on coal and oil fired boilers in British power stations is presented giving average figure of coal and oil ash analysis and the constituents of flue gases assuming 30 per cent excess air and illustrating typical cases of high and low temperature corrosion. The formation of SO_3 and its rôle in the corrosion mechanism are discussed. It is concluded that by rigid control of the combustion conditions most of the difficulties can be avoided.

Experience of Corrosion and Erosion in Slagging Furnaces. H. Bendfeldt. *Mitt. V.G.B.* No. 65 1960 (Apr.), 117–25 (in German).

The occurrence of tube failure in boilers with vertical cyclones after 26,000 h of operation could be traced to CO formation at lower loads when the secondary air velocity was insufficient. By increasing secondary air volume and velocity CO formation could be suppressed but the decrease of the CO_2 content from 16.5 to 15 per cent and increase of the O_2 content to 3.5 per cent makes slagging operation below 75 per cent of full load impossi-

ble. The secondary air nozzles are to be provided with special dampers to ensure uniform air velocity at all loads. The vertical cylindrical arrangement of cyclone and radiant furnace is regarded as particularly suitable for good gas flow and prevention of difficulties caused by corrosion and erosion but boilers operating with widely fluctuating loads are better served by dry-bottom furnaces.

Experience on a Benson Boiler Fired by Blast Furnace Gas and Oil—Especially with Regard to Vanadium Corrosions. F. Sieverding. *Mitt. V.G.B.* No. 65 1960 (Apr.), 78–87 (in German).

During the first operating period with 2550 h of gas firing and 4300 h of oil firing only dusty easily removable deposits and no corrosion were found. During the second period with 5600 h of oil firing tube failure, heavy, hard deposits, corrosion of tube supports, refractories and boiler casing plates occurred caused by incomplete combustion due to insufficient preheating after a change of oil. In consequence dolomite was added in the furnace and preheated air circulated between the boiler casing and the refractories. After a further 3000 h of oil firing fouling was much reduced though the very hard deposits in the gilled tube air preheater were again present and further tube supports were corroded by attack from V_2O_5. Analyses of the deposits are tabulated and discussed.

Low-Temperature Corrosion in Oil-fired Boilers. G. Weber. *Mitt. V.G.B.* No. 65 1960 (Apr.), 69–78 (in German).

A review of the literature of mainly American, British and Swedish origin.

Flue Gas, Ash and Dust

Combined Flue Gas Dedusting in Boiler Plants. K. Schäff. *Mitt. V.G.B* No. 65 1960 (Apr.), 88–91 (in German).

After the conversion of the boilers at Lünen power station to slag-tap firing it became necessary to supplement the fly ash separation in the electrostatic precipitators by the installation of multicyclones. The reasons for installing these after the precipitators are detailed and figures presented of total separation efficiency achieved; this varied between 0.977 and 0.88 per cent depending on the design of the multicyclones. Wear on the cyclones has been very heavy.

State of Development of Electrostatic Precipitators for Flue Gases. H. Brandt. *Tech. Überw.* 1960, 1 (May), 177–81 (in German).

This review deals with the design of electrodes, generation of high voltages, difficulties and limitations of electrostatic precipitation, differences in the dust from slagging and dry bottom furnaces and correction factors to be applied to the dust removal efficiency where fuel and operating conditions differ from those on which the original design was based.

Influence of Flue Gas Emission on Design of Steam Power Stations. H. Eickemeyer. *Energie* 1960, **12** (May), 198–206 (in German).

The factors influencing flue gas emission from a chimney and its dispersion in the air are discussed. Wind tunnel model tests for obtaining optimum height of chimney and flue gas exit velocity for the Stuttgart-Gaisburg power station are described. The optimum solution could not be applied for architectural reasons.

Flyash Cuts Brentwood Paving Costs. N. Falkin. *Elect. Wrld* 1960, **153** (May 2), 42.

The site at Brentwood is a center for the storage of vehicles and materials belonging to the Long Island Lighting Co. In constructing the base course a 6-in. layer of soil was compacted, a 2-in layer of aggregate added together with 60 lb/sq. yd of fly ash and 30 lb/sq. yd of hydrated lime and water, thoroughly mixed and compacted to 95 per cent density. The compressive strength reaches 1500 psi.

Power Generation and Power Plant

What May Be Ahead in Power Production. G. B. Warren. *Mech. Engng* 1960, **82** (May), 61–5.

It now appears likely that in the U.S.A. the installed capacity required will be 600,000 Mw by 1980, i.e., 3 to 4 times the 1959 capacity. Turbogenerators of up to 1000 Mw will be used, up to 400 Mw cross-compound, above that single shaft or cross-compound running at 1800 rpm. Neither gas turbines nor nuclear power are likely to contribute more than 10 per cent to the total demand.

European Energy Needs. Anon. *Iron & Coal Tr. Rev.* 1960, **180** (May 20), 1113.

E. Hirsch, president of Euratom, estimates that by 1980 Europe's energy needs will have risen from the present 450 million to 800 million tons coal equivalent. This would require the building of more than 250 units of 150 Mw and their construction should start at once. F. H. S. Brown, deputy chairman of the CEGB, thought that nuclear power was at present marginally uneconomic but developments promised competitiveness with coal by about 1970.

Power for Peaking. C. C. Franck. *Combustion* 1960, **31** (May), 28–38.

A general review of the possibilities and economics of designing power stations for peak load supply.

American Power Conference in Review—I. Anon. *Combustion* 1960, **31** (May), 43–7.

Abstracts of papers dealing with: (1) Concrete chimneys; (2) tube life in high temperature boilers; (3) selection of boiler feed pumps; (4) stability of austenitic steels at 1450F; (5) mechanical draught fans; (6) peak load supply; (7) packaged oil, gas and coal fired boilers for up to 50,000 lb/h; (8) slag tap boilers.

Application of Heat Storage in Nuclear and Conventional Power Stations. Fr. Marguerre and Fe. Marguerre. *Elektwirtsch.* 1960, **59** (May 20), 320–6 (in German).

Heat storage of up to 35 per cent of the primary output can reduce the cost of a unit from a conventional power station by 5–7 per cent, that of a unit from a nuclear power station by 15 per cent. Combination of heat storage and superheating by fossil fuel would reduce the cost of a unit generated in a nuclear station below that generated in a conventional station. Three appendices give the detailed calculations.

Potential Heat in Fuel: Direct Conversion to Electricity. M. W. Thring. *J. Inst. Fuel* 1960, **33** (June), 294–9.

Direct conversions in the fuel cell, thermo-electric generation and electric gas breaking and their prospects and limitations are discussed.

Boundary Dam Generating Station, Canada. Anon. *Engng Boil Ho. Rev.* 1960, **75** (June), 172–8.

This station contains at present two 66 Mw units but is to be extended to a total capacity of 352 Mw. The two boilers are each rated at 600 klb/h, 875 psi and 915 F and designed to burn lignite with a C.V. of 6000–7000 Btu/lb and a moisture of 30–35 per cent. The description includes the coal and ash handling plant, boiler and turbogenerators, controls, water treatment, electrical system and auxiliaries.

Planning of Power Stations in the Cottbus Region—A Development towards Standard Plans for Large Power Stations. S. Kowallik. *Energietechnik.* 1960, **10** (May), 188–92 (in German).

Fuel (brown coal) and river water appear to be sufficient for the erection of four power stations of the same fundamental design each of 1200 or 1800 Mw final output. The first, Lübbenau, will have 3 sections, one of six 50 Mw sets, one of six 100 Mw sets

and one of four 100 Mw sets. The second station, Vetschau, will have 3 sections, 2 with 6–100 Mw sets, the third possibly with 3–200 Mw sets but 6 boilers. Two further stations of 1200 or 1800 Mw are to be erected later. The steam parameters are standardised at 159 atü and 530/525 C, the cooling water cooled in mechanically ventilated towers. The reasoning behind these decisions are outlined.

On the Line at Lake Creek. E. E. Wawak. *Heat Engng* 1960, **35** (Mar./Apr.), 114–7.

Unit No. 2 at Lake Creek Station of Texas Power and Light Co. consists of a gas-fired, natural circulation boiler rated at 1600 klb/h at 1935 psi and 1005/1005 F and 160 Mw turbogenerator. Provision is made for lignite firing at a later date, but at present only 18 gas and oil firing burners are installed.

The 125 Mw Unit-type Installation at Langerbrugge Power Station, Belgium. J. Ryffranck. *Votre Electricité* 1960, **31** (Feb.), 10–40 (in French).

The 150 Mw station with five turbo-alternators and nine boilers, including one Benson boiler, has been extended by a 125 Mw unit-type installation comprising a 350/380 t/h, 127 kg/cm², 540/535 C reheat outdoor-type natural-circulation pff boiler by Cockerill-Stein and Roubaix driving a 125 Mw hydrogen-cooled turbo-alternator by Ateliers de Construction La Meuse and A.C.E.C. A full description of the plant is given.

From C.E.G.B. Digest 1960, **12** (June 4), 1417.

The Steam Generator and Preheating Plant for the 100 Mw Unit of the Stuttgart-Gaisburg Heat-Power Station. H. Eickemeyer. *B.W.K.* 1960, **12** (May), 211–7 (in German).

The reasons underlying the design of the Benson boiler (922 klb/h, 2630 psi, 1010/1010 F), controls, air admission, slagging furnace, electrostatic precipitator and regenerative feed water preheating are discussed and details of design given. The steels used in the various parts of the boiler are tabulated. The optimum thermal efficiency when supplying the maximum amount of steam for heating (200 t/h) is 48.55 per cent.

Materials and Manufacturing Processes

Metal Borides and Carbides—Materials of the Future. W. R. Benn. *Ind. Engng Chem.* 1960, **52** (May), 40A-4A.

Borides and carbides are extremely hard and brittle but possess high temperature stability. Ways of overcoming brittleness are indicated. The essential properties of various borides and carbides are tabulated.

A Creep-resisting Steel Containing 7 Per Cent Cr. G. A. Mellor and S. M. Barker. *J. Iron & Steel Inst.* 1960, **194** (Apr.), 464–74.

A ferritic steel for operation at 600–650 C suitable for superheater tubes has been developed containing 7 per cent Cr with additions of 2 per cent Mo and 0.5 per cent Ti. The results of tests made with this steel are reproduced and discussed.

A New Low-Alloy Steel for High Temperature and Pressure Boiler Drums. T. M. Slutskaya. *Autom. Weld.* 1959, (Oct.), 125–7. *B.W.R.A. Transl.*

The composition of the steel is: 0.12–0.18 per cent C, 0.3–0.6 per cent Si, 1.25–1.65 per cent Mn, 0.8–1.1 per cent Cr, 0.4–0.8 per cent Ni, 0.05–0.2 per cent V, not more than 0.3 per cent Cu, 0.04 per cent S and 0.035 per cent P. It has high creep strength, and is easier to weld and resistant to corrosion cracking. Recommendations for welding by the electro-slag process are given.

Some Characteristics of Integron Mild Steel Tubing for Heat Exchangers in Nuclear Power Stations. F. E. Astbury and L. H. Toft. *Metallurgia* 1960, **61** (May), 193–200.

Integron tubing is produced by I.C.I. Ltd. by cold rolling plain tubes to obtain circumferential fins. Metallurgical characteristics and fatigue resistance in the "as-finned" and in the heat-treated conditions have been studied, as well as effect of service temperature on tensile properties and residual stress and of welding on parent metal. Heat treatment does not appear necessary for the conditions obtaining at Bradwell and Berkeley.

Boiler Model Tests of Materials for Steam Generators in Pressurized Water Reactor Plants. E. Howells, T. A. McNary and D. E. White. *Corrosion* 1960, **16** (May), 111–5.

Heat exchanger models made of stainless steel, carbon steel, Croloy 2¼, Croloy 16–1, nickel, Inconel and Monel were tested at a pressure of 2000 psi and 600 F for about 500 hr. The materials were then subjected to metallurgical examination. The occurrence and extent of corrosion and stress-corrosion cracking in these steels are discussed.

Semi-Automatic CO_2 Butt Welding of Main Pipe Lines without Permanent Backing Rings. V. Ya. Dubrovetskii and V. P. Livinskii. *Autom. Weld.* 1959 (Oct.), 106–10. *B.W.R.A. Transl.*

The semi-automatic welding with CO_2 as shielding gas of steel pipes with a wall thickness of 8–10 mm is described.

Automatic CO_2 Butt Welding of Thin-Walled Tubes. D. A. Dudko, M. D. Litvinchuk and V. S. Mechev. *Autom. Weld.* 1959 (Oct.), 100–5. *B.W.R.A. Transl.*

A procedure for obtaining sound welds in steel tubes with wall thicknesses of 1–1.5 mm is described.

Service Failures of Pipe Weldments. H. Thielsch. *Weld. J.* 1960, **39** (May), 488–95.

The reasons for defective welds remaining undetected despite the application of the usual non-destructive testing methods are discussed. Methods relating to design, electrode and base metal composition to reduce the possibility of the occurrence of faulty welds are presented.

Instruments and Controls

Improvement of Pressure Control in Steam Generators. H. Zwetz. *B.W.K.* 1960, **12** (May), 206–8 (in German).

The new control system is based on the relationship between rate of firing and steam flow, taking into account the storage capacity of the boiler. The new scheme also improves the temperature control.

We Monitor Silica Automatically in 2600-psig Boilers. T. Finnigan. *Pwr Engng* 1960, **64** (May), 58–9.

Since the silica carry-over in the steam is largely a function of the silica content of the boiler water and this is easier to determine accurately, Niagara Mohawk Power Corp. have introduced the Technicon Autoanalyser for the continuous taking and analysing of boiler water samples of two boilers, the instrument being switched from one boiler to the other every 15 min. The silica content of the steam should not exceed 0.02 ppm and the limit for the boiler water is thus set at 0.3 ppm. When this is approached the pressure is reduced and the boiler blown down until the correct concentration is established.

Automatic Protection for a Gas-Cooled Reactor. B. E. Elthan and M. J. Cowper. *Nucl. Engng* 1960, **5** (June), 243–9.

Automatic protection against an excessive rise in fuel element temperature and release of fission products is discussed and the instrumentation provided for this purpose described.

Nuclear Energy

Nuclear Power Prospects. Anon. *Elect. Times* 1960, **137** (June 9), 927–9.

Sir William Cook has predicted that the advanced gas-cooled reactor the prototype of which is now under construction, will be able to produce a unit cheaper than a modern conventional power station. The prototype being built at Windscale is described; it will operate with a coolant inlet temperature of 250–325 C and an outlet temperature of 500–575 C, part stainless steel and part beryllium clad duster fuel elements and 1.25 per cent enriched uranium dioxide. The net station efficiency is expected to be 38 per cent.

Nuclear Power for Ship Propulsion. J. E. Richards. *J. Inst. Fuel* 1960, **33** (June), 271–83.

The following are discussed: (1) Type of ship; (2) tanker economics; (3) nuclear fuel cycles; (4) types of reactors; (5) assessment of reactor types; (6) characteristics of civil plutonium; (7) plutonium burning fuel cycle; (8) application to marine propulsion; (9) conclusions; these show that no clear line can be drawn of development towards an economic reactor for merchant ships.

5th Nuclear Power Report. D. Braymer. *Elect. Wrld* 1960, **153** (May 16), 63–82.

This report consists of: (1) An outline of the plans made by AEC to make nuclear power competitive by 1968; (2) a review of the eight reactors built, building or planned which show the greatest promise; (3) a complete list of civilian nuclear power and experimental reactor projects built or planned in the U.S.A. The eight reactor types are: (1) Pressurized water; (2) boiling water; (3) organic cooled; (4) enriched gas cooled (5) sodium graphite thermal; (6) sodium cooled fast; (7) heavy water moderated; (8) aqueous homogeneous.

Progress Review No. 47: The Engineering Aspects of Nuclear Power. K. P. Gibbs. *J. Inst. Fuel* 1960, **33** (May) 238–47.

The review deals with: (1) Gas-cooled, graphite-moderated reactors; (2) fuel elements; (3) moderator; (4) pressure vessel; (5) shielding; (6) charge/discharge equipment; (7) instrumentation and control; (8) boilers; (9) CO_2 ductwork and circulators; (10) future British reactors.

American Nuclear Congress and Atomic Exposition. No. 1—IV. Anon. *Engineer* 1960, **209** (June 3), 954–6, (June 10), 993–6, (June 17), 1030–2, (June 24), 1086–8.

The congress held in April 1960 surveyed progress in the nuclear field.

Flow Inversion in Gas-cooled Reactors. H. Benzler. *Atomkernenergie* 1960, **5** (May), 165 (in German).

It is shown that in gas-cooled reactors with vertical downward flow of the cooling gas an inversion of the flow at low load may occur. It is suggested that this situation can be avoided if during starting about 5 per cent of the full-load gas volume is recirculated.

Grinding, Screening and Filtering

Experiments on Determining the Particle Motion in Gas Jets and the Stress Mechanism in Fluid Energy Mills. H. Rumpf. *Chem. Ing. Tech.* 1960, **32** (May), 335–42 (in German).

Since the boundary conditions for jet formation and particle motion in such mills are not yet sufficiently defined individual jets have been investigated by stroboscopic measurements. From the particle velocity the jet velocity along the particle path can be calculated. The maximum velocity of a particle in the jet axis can be predetermined. Estimates of the influence of turbulence on particle motion are presented. Comminution in a fluid-energy mill is mainly confined to the neighborhood of the nozzle exit.

Analysis and Testing, Research

Rapid but Accurate Method of the Determination of the Calorific Value of Coals. Moreau. *Chal. et Ind.* 1960, **41** (Apr.), 105–12 (in French).

An improved method worked out by Georgiadis is described enabling at least 8 determinations per day to be made against 4–5 by the classical method. An estimation of the possible errors and correction factors are included.

Recommended Practice for Radiographic Inspection of Fusion Welded Joints. Circumferential Butt Joints in Steel Pipes up to 2 in. (50 mm) Wall Thickness. Intern. Inst. Welding. *Brit. Weld. J.* 1960, **7** (June), 410–4.

Simplified Method of Measuring Surface Areas by Gas Adsorption. R. Haul and G. Dümbgen. *Chem. Ing. Tech.* 1960, **32** (May), 349–54 (in German).

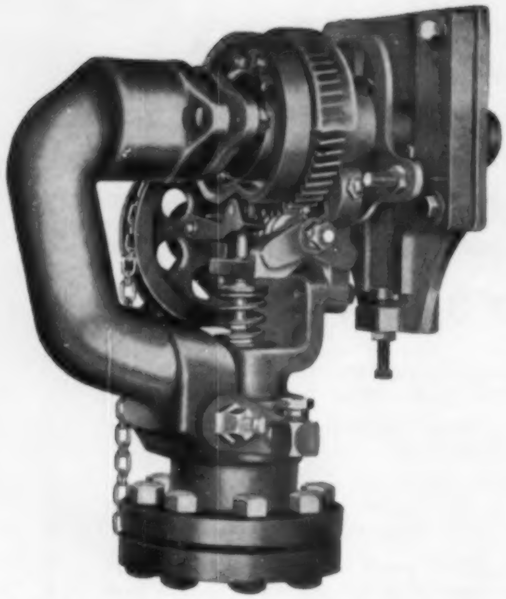
A simplified and rapid method has been worked out on the basis of the BET method. Reproducibility is high and the values obtained are 5–10 per cent lower than those of the BET method.

Editor's Note:

Due to a shortage of reviewable material the section "Technical Book Reviews" by John H. Cruise will appear next month.

Advertisers' Index

(Continued on page 71)



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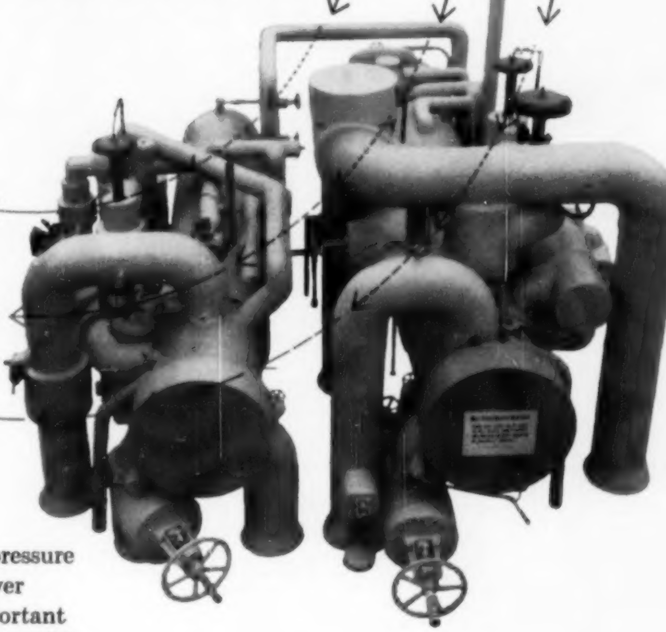

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